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Reports of Committees on

PROCEEDINGS

MEMOIRS

The Effect of Various Fasteners on the Fatigue Strength of a Structural Joint

A Report of an Investigation Conducted at the Department of Civil Engineering, Northwestern University, in Cooperation with The American Institute of Bolt, Nut and Rivet Manufacturers

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Purposes and Scope of the Investigation

The purposes of this investigation were to determine the effect of various fasteners on the fatigue strength of structural joints and to determine the clamping force exerted by various fasteners. Supplementary studies were made of the effects of various fasteners on the slippage of a joint and of the plate tension on the reduction in clamping force of bolts.

Three groups of structural joints, identical except for the fasteners, were subjected to fully reversed cycles of fatigue loading. The selected fasteners were hot-driven rivets, cold-driven rivets, and bolts. These groups of joints, however, were identical as to kind of steel, dimensions of specimens, number and pattern of fasteners, and length of grip. The structural joint had a square pattern of nine ¾-in. diameter fasteners. This joint was selected to be representative of those frequently used in structural practice. The maximum tension–shear–bearing ratio usually allowed in design specifications is 1.00–0.75–1.50. The tension–shear–bearing ratio for the main series of tests was 1.00–0.57–0.89. It was considered that more than three rows of rivets would not materially affect the results and that the distribution of load to the rivets would be similar to that obtained in a large joint.[1]*

The investigation consisted of a group of static tests and a group of fatigue tests on the typical joints. The static tests were made to determine the following: Tensile properties of the material; physical properties of the driven rivets; initial tension of the hot and cold-driven rivets; the clamping force of bolts; and the effect of plate tension on the clamping force of bolts. The fatigue tests were made to determine the fatigue strength of the three groups of structural joints and of a special group of bolted joints. Several ranges of reversed cycles of loading were considered in this series of tests. The special group of joints was included to determine the influence of a smaller grip and a larger ratio of pitch to thickness on the fatigue strength of bolted joints.

Acknowledgments

These tests are part of an investigation conducted by the Department of Civil Engineering at Northwestern University and by the American Institute of Bolt, Nut, and Rivet Manufacturers.† The program was initiated by the late G. A. Maney of

* See bibliography at end of this report.
† Now the Industrial Fasteners' Institute.

REVISIONS AND CORRECTIONS

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Changes in the text for correction of typographical errors, and to take account of revisions, deletions and additions requested by committees. For other revisions and corrections of committee reports, see "Discussion."

Page 90, add the word "insert" at the beginning of the sixth line from the top and delete it from the third line. In the ninth line from the top add an asterisk after the word Signals. The footnote at the bottom of the page should follow the thirteenth line from the top of the page.

Page 97, delete CI&L from the heading CI&L, R&E, Cost.

Page 164, in heading at the top of the page the word "Plant" should be deleted.

Page 168, the second line in subparagraph (a), "form" should read "from."

Page 188, in paragraph B–1, line 2, change "are" to "is."

Page 208, final paragraph and two lines on following page withdrawn.

Page 234, 235 and on the inserts, in the captions referring to repair shops for diesel switcher locomotives, delete the word "switcher."

Page 330, after the first paragraph at the top of the page, the heading "Mechanization" should be inserted.

Page 362, in the last sentence in the next to the last paragraph, change "Decrease" to "Any change."

Page 365, in the seventh line from the bottom of page, starting, "And bonding, waterproofing—," change the "And" to "Any."

Page 367, at the top of the page, the words "and tested" should be added to the first sentence after the first table.

Page 373, in the first paragraph, the 12th line should be deleted and the words "the absolute volume of coarse aggregate in a unit-volume of dry-rodded coarse aggregate." inserted in place of it.

Page 376, Change fourth line from top to read: "such as dry-loose, damp-loose, etc."

Page 407, in the last sentence in paragraph 18, the word "mental" should read "metal."

Page 440, in section six, at the top of the page, the headings, "Timber and Piling" should be omitted and the numbers under the heading Piling moved to the left in the line with the other numbers in the section.

Page 444, in the paragraph referring to page 429, Article 107, Impact (B) 2, in the third line, "as" should read "at."

Page 558, Note below table 4 should read "Note:—indicates figures are not available" in Columns 1, 2, 3, 4, 5.

Page 317, under the table "Summary of Economies Realized," in the column headed "Daily Output of Machine," "600 ft. border ballast" should read "600 ft. center ballast."

Page 505, change twelfth line from bottom of page to read: "Alternate structural units having a depth of corrugation of more than—."

Page 654, ninth line from top of page, change word "titled" to "tilted."

Static Tests

The purposes of the static tests were to ascertain that the materials used were similar in all of the joints and to provide data for the interpretation of the results of the fatigue tests. Standard tests were made to determine the tensile properties of the plate material and the physical properties of the driven rivets. In addition, special tests were performed to evaluate the initial tension of the hot and cold-driven rivets and the clamping force of the bolts. Static tension tests were performed on two bolted joint specimens to determine the coefficient of friction of the plates, the effect of Poisson's ratio on plate and bolt strain, and the effect of plate tension on the clamping force of bolts.

Tensile Properties of the Plates

Material cut from the plates at the upper ends of the grips was used to determine the tensile properties. The coupon specimens were 0.505 in. in diameter machined from the ¾-in. plates and rectangular specimens ⅜ in. by ½ in. taken from the ⅜-in. plates. The longitudinal axis of the coupon coincided with that of the fatigue specimen. Two SR-4 gages were mounted on diametrically opposite sides of each specimen to determine the stress-strain curves.

All material had approximately the same properties and met the requirements of the ASTM Specification A-7, Steel for Bridges and Buildings. Figs. 1 and 2 show typical stress-strain curves obtained from each type of coupon. The following are average results for the 12 tests made:

Yield stress	34,400 psi. (33,000 to 36,000 psi.)
Ultimate stress	62,700 psi. ± 400 psi.
Elongation in 2 in.	28.6 percent
Modulus of elasticity	29,600,000 psi.

Physical Properties and Clamping Force of Driven Rivets

Variation in the fatigue strength of the different type joints was dependent on the filling of the holes and the clamping force of the fasteners. The slippage readings on the joints under fatigue loading afforded a measure of the filling of the holes. Relaxation tests were made to determine the initial tension of hot and cold-driven rivets. In addition, the physical properties of the driven rivets were determined. As no additional specimens were available for these tests, the rivets were taken from the fatigue specimen after failure.

Relaxation tests were made to determine the initial tension of hot and cold-driven rivets. The procedure for these tests was similar to that developed by W. M. Wilson.[6] After fatigue failure occurred, joints were sawed into strips containing three rivets. Plugs of tool steel were placed in the heads of the rivets with a tight fit at the shank and with a loose fit in the head. These plugs were drilled to receive the points of the extensometer. Because the driven head of the cold-driven rivets was only ¼ in. thick, plugs could not be conveniently inserted. These heads were surface ground and then center drilled. Initial readings were taken on all rivets. The strips were sawed into units containing a single rivet and were then machined to remove the center plate. The length of the rivets was measured after the center plate was removed. The clamping stress in the rivets was computed as the change in length divided by the length and multiplied by the modulus of elasticity (30,000,000 psi.). The grip in all cases was 1½ in.

The average clamping stress was computed as 12,000 psi. for the hot-driven rivets and 3400 psi. for the cold-driven rivets. Table 1 lists the results of the individual tests.

Northwestern University, and by H. H. Lind, president, and W. C. Stewart, technical advisor, of the American Institute of Bolt, Nut, and Rivet Manufacturers.

The author particularly appreciates the many helpful suggestions of Professor Frank Baron during the conduct of the tests and the writing of the report.

Introduction

This investigation was made because little information was available as to the relative fatigue strength of structural joints fabricated with different types of fasteners. Much work had been done by others as to the fatigue strength of joints fabricated with hot-driven rivets. No comparative studies, however, had been made of joints fabricated with cold-driven rivets or bolts. In certain cases, cold driving has recently become an acceptable practice in shop fabrication. In addition, the use of bolted connections for conditions of fatigue loading has been considered objectionable by many structural engineers.

The first extensive tests of riveted joints were reported in 1838 by William Fairburn. Since then, many investigators have interested themselves in the behavior of riveted joints subjected to static loads. H. F. Moore and J. B. Kommers in 1921 reported the first important series of fatigue tests directly related to riveted joints. Their paper dealt with the fatigue of metals and was followed by a similar paper in 1923.[2] J. S. Wilson and B. P. Haigh in 1922 published the results of fatigue tests conducted on plates with open holes.[3]

The Technical College at Stuttgart undertook a fatigue investigation in 1930 for the Deutscher Stahlbau–Verband and the Deutsche Reichsbahn–Gesellshaft. This investigation was to determine the material requirements and the design specifications necessary for riveted joints. This work was recorded by K. Schaechterle and is summarized in the bibliography compiled by A. E. Richard de Jonge.[4] This bibliography summarizes all work conducted on riveted joints previous to 1942. It indicates that Otto Graf published nine articles on the fatigue of structural materials and of riveted and welded joints. Among the variables studied by Graf were the effect of mill scale, holes, and grooves on the endurance limit of steel; the effect of small fluctuations of load on a bar with high initial stresses; the fatigue strength of alloy steels; the effect of placing rivets in open holes; the endurance limit of butt joints with one, two, and three rivets; the bending stresses and distribution of load on a rivet; and the effect of clamping force, the tension-bearing ratio, and of the tension-shear ratio on the fatigue strength of riveted joints.

In 1938 W. M. Wilson and F. P. Thomas reported the results of fatigue tests made in connection with the construction of the San Francisco–Oakland Bay Bridge, California.[5] Several specimens were designed for rivet failure and other specimens for plate failure. Among the variables studied were the grip of the rivets; the transverse distance between rivets; the relationship between unit shear, unit bearing, and unit tension; combinations of carbon-steel and manganese-steel rivets with carbon, silicon, and nickel steel plates; and various methods of making holes.

On the basis of these earlier investigations, the present study was limited to obtaining a comparison of the fatigue strength of structural joints in which the only variable was the type of fastener. An exploratory program of this investigation was outlined in the fall of 1944 and was sponsored by the American Institute of Bolt, Nut, and Rivet Manufacturers. Previous to this investigation Northwestern University had begun a series of tests to determine the torque-tension relationship of various sized bolts. The latter work has been completed and is reported elsewhere.[6] This work was used as a basis for estimating the clamping force of the bolted specimens during their assembly.

TABLE 1.- CLAMPING FORCE & PHYSICAL PROPERTIES OF RIVETS REMOVED FROM SPECIMENS AFTER FATIGUE FAILURE

Spec.	Strain In/In	Clamping Stress Psi.	Rivet Dia. Center of Rivet In.	Yield Load Lb.	Ultimate Load Lb.	Tensile Yield Nom. Dia.	Stress Psi Act. Dia.	Tensile Ultimate Nom. Dia.	Stress Psi Act. Dia.	Elong. Percent in 1½"
Hot-Driven Rivets										
1	0.00040	12,000	0.8093	19,250	35,950	43,600	37,400	81,400	70,000	43.8
2	0.00033	10,000	0.8066	19,200	35,900	43,500	37,600	81,300	70,400	42.7
3	0.00044	13,200	0.8078	18,900	34,650	42,800	36,800	78,500	67,600	37.5
4	0.00039	11,700	0.8073	17,800	36,900	40,300	34,800	83,500	70,600	43.8
5	0.00043	12,900	-	19,300	36,700	43,700	-	83,100	-	43.8
Av.	0.00040	12,000	0.8077	18,900	36,100	42,800	36,600	81,600	69,700	42.3
Cold-Driven Rivets										
a. Rivets failed by shearing of the driven head.										
1	0.00005	1,500	*0.8193	19,500	34,600	Flat or Driven Head Sheared Off				
2	0.00012	3,600	*0.8193	20,400	34,900					
3	0.00010	3,000	*0.8195	20,500	35,300					
4	0.00018	5,400	*0.8207	22,400	35,000					
5	0.00014	4,200	*0.8215	22,300	34,550					
6	0.00009	2,700	*0.8193	21,750	33,950					
Av.	0.00011	3,400	*0.8199	21,100	34,700					
b. Rivets failed by tension in shank.										
1			*0.816	x	35,400			80,000	67,700	33.3
2			*0.817	x	35,400			80,000	67,400	33.7
3			*0.815	x	35,300			79,800	67,700	33.3

* These readings were taken at the center of the rivet. The average diameter was about 0.813" at a distance of 1/4" from the manufactured head. The diameter was 0.832" at the same distance from the flat or driven head.

x Yield could not be determined by drop of the beam.

Diameters of the rivets were also carefully measured. The specified diameter of the rivets was ¾ in. and the specified diameter of the holes was 13/16 in. or 0.8125 in. Measurements were made at transverse sections midway between heads of rivets. The average diameter at the center of the hot-driven rivets was 0.8077 in., and of the cold-driven rivets, 0.8199 in. In addition, the diameter of the cold-driven rivets was 0.832 in. at the driven head and 0.813 in. at the manufactured head.

Rivet specimens were tested to failure in tension. The yield point was indicated by the falling off of the indicated load on a hydraulic machine. The elongation in a 1½-in. length of the hot-driven rivets was 42.3 percent. In these tests the driven or flat heads of the cold-driven rivets failed in shear. The measured elongation of the shank was negligible, and the ultimate load did not indicate the ultimate tensile stress of the material. The ultimate load for the hot-driven rivets was 36,100 lb.; for the cold-driven rivets, 34,700 lb. The yield lead for the cold-driven rivets was slightly higher than that for the hot-driven rivets. Fig. 3 shows a cold-driven rivet and two hot-driven rivets after failure. Table I tabulates the results of the individual tests.

It is emphasized that the results indicated for the cold-driven rivets refer to the shearing strength of the driven head and are not indicative of the tensile properties of the rivet shank. The height of the driven heads was between 3/16 in. and ¼ in., thus meeting the tentative specifications of the American Institute of Bolt, Nut, and Rivet Manufacturers.

In the above mentioned tests, the rivet specimens were tested with only the middle plate removed. The two outside plates were ⅜ in. thick. A fixture was used with 5/16-in. fingers which extended under the plates to the shank of the rivet. The plates and the fixture bent considerably before the rivet failed. It was thought that this bending contributed to the failure of the cold-driven rivets in shear of the driven heads.

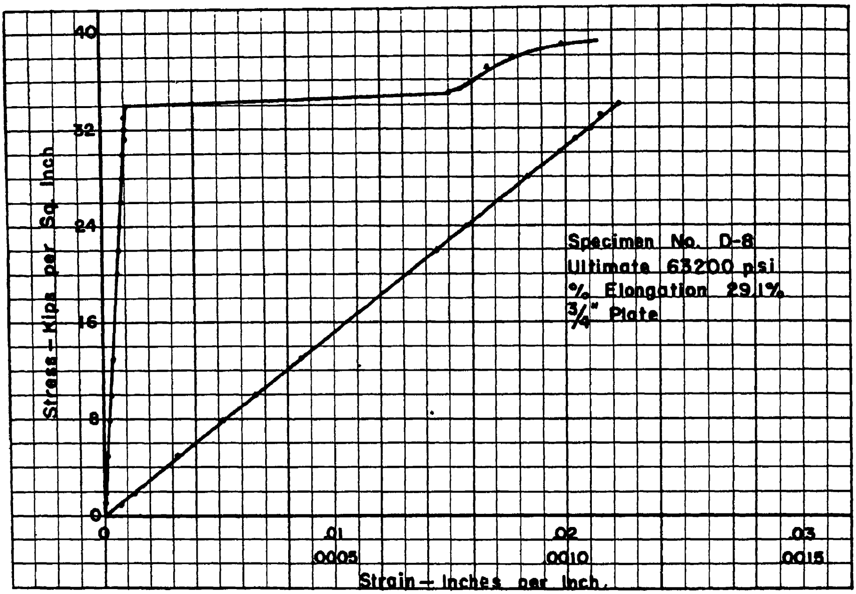


Fig. 1.—Typical Stress-Strain Curve for Steel Plates from Fatigue Specimens Used in Major Portion of Tests.

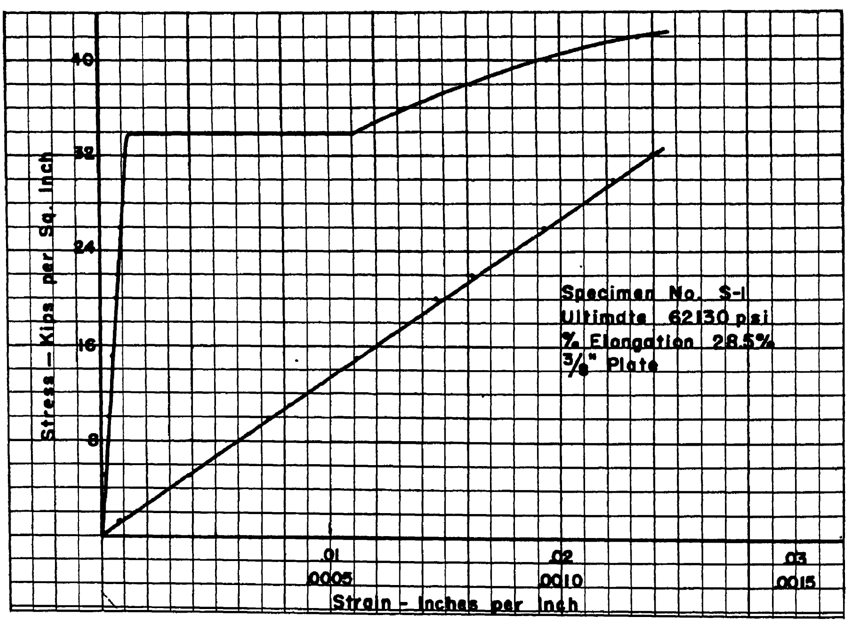


Fig. 2.—Typical Stress-Strain Curve for Steel Plates Used in Special Bolted Fatigue Specimens.

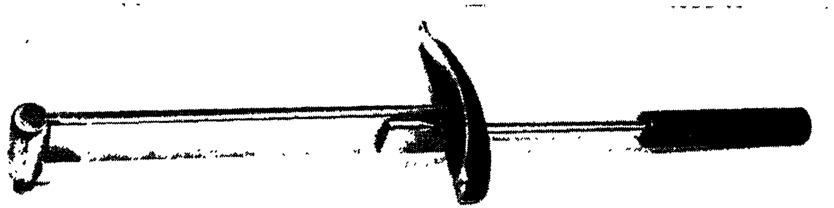


Fig. 4.—Sturtevant 300 ft.-lb. Torque Wrench Used for All of the Bolted Joints.

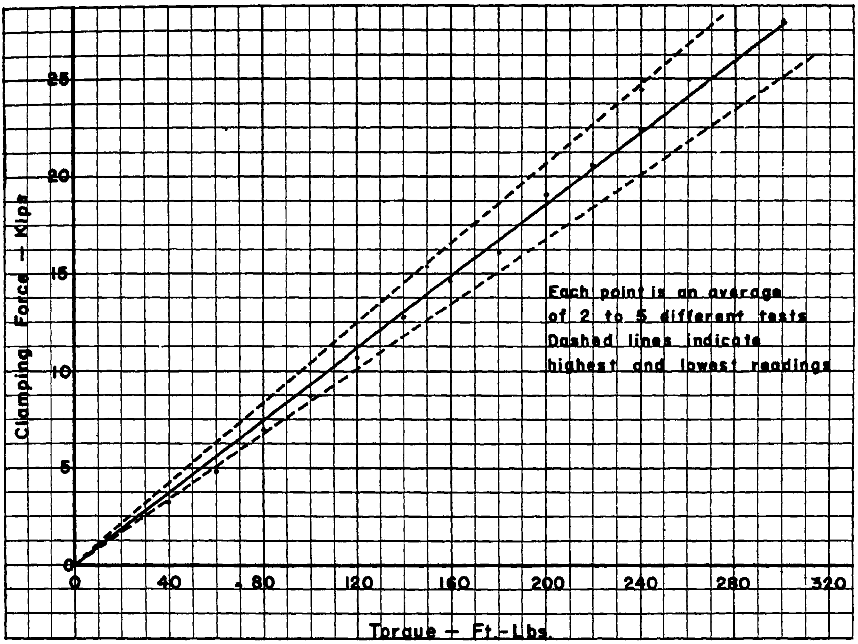


Fig. 5.—Torque–Tension Relationship of ¾ in. 1038 Bolts with Heavy Semi-Finished Nuts and Carburized Washers.

Although the clamping force was initially estimated by means of the torque wrench, the total elongations of the bolts were also measured.

Throughout the static and fatigue tests of the bolted joints, the clamping force was controlled by the torque applied to the nuts. The torque-tension relationship was determined for bolts of the same grip and for similar nuts and washers as shown in Fig. 5. As shown previously, this relationship is checkable and quite reliable.[6] This relationship had been obtained for bolts of ¼ to 1 in. diameter and with fine or coarse threads. In these cases the torque was equal to a constant times the nominal diameter times the clamping force. ($T = R \times D \times P$). The theorectical value of R varies from 0.188 to 0.210, depending on the pitch of the thread and diameter of the bolt. A coefficient of friction of 0.15 was considered in obtaining these values. The tests showed that sufficient accuracy is obtained by using a value of 0.2 for R. The average deviation

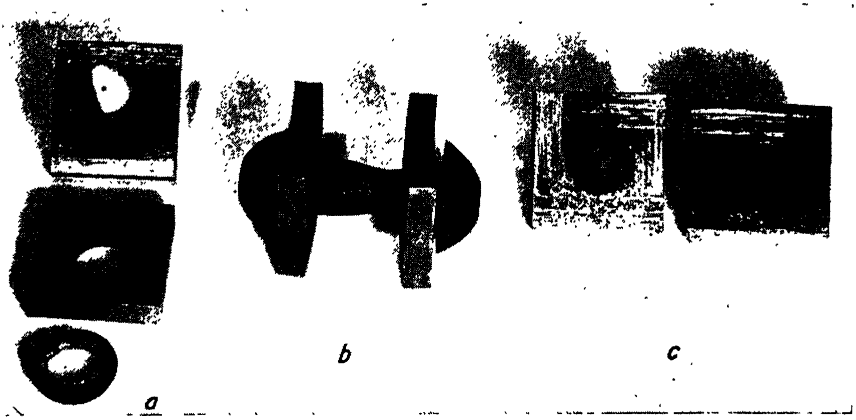


Fig. 3.—(a) Cold-Driven Rivet Tested in Tension; (b) and (c) Hot-Driven Rivets Tested in Tension. Note Curvature of Plates in Testing.

To check this, a new fixture was made, which completely encircled the shank of the rivet after all the plates had been removed. No clamping force was present on the shank of the rivet. Three cold-driven rivets were tested with this fixture. In each case failure now occurred in the shank. These tests indicate the extent to which the type of failure is influenced by the type of fixture. The average ultimate stress was 67,600 psi. The average elongation in the 1½-in. length was 33 percent. The yield point could not be observed by the falling off of the indicated load.

Bolt Calibration

The bolted specimens were expected to resist loads purely by plate friction; there should have been no shear or bearing forces on a bolt. Holes were drilled 1/16 in. larger than the body diameter of the bolt to insure easy assembly and also to eliminate shear and bearing.

As the joint was to resist the load entirely by friction, the maximum clamping force that could be obtained was desired. For this reason, high tensile bolts made from SAE 1038 steel were used. The nominal diameter of the bolts and the rivets was ¾ in. These bolts were specified to have a minimum yield point of 85,000 psi. and an ultimate of 105,000 psi. All bolts tested had a yield point above 100,000 psi., based on the mean area of the bolt thread, which was 0.334 sq. in. To make certain that the clamping force was fully developed and sustained, heavy semi-finished milled-from-bar nuts were used.

It was observed in torque-tension tests prior to the fatigue testing that the bolts were exceeding the elastic limit at a low clamping force. Also, the clamping force of these bolts was not in proportion to the applied torque except for low values of torque. It was also observed that due to torque, the nut face and bolt head were galling and cutting the hot-rolled plates. Regular and cyanided washers and alloy plates were tried with the same results. However, machine washers carburized to a depth of 0.025 to 0.032 in. resisted the galling and cutting. Carburized washers were used throughout these tests.

The torque was measured with a Sturtevant torque wrench as shown in Fig. 4 of 0 to 300 ft.-lb. This range could be increased to 600 ft.-lb. by the use of extensions.

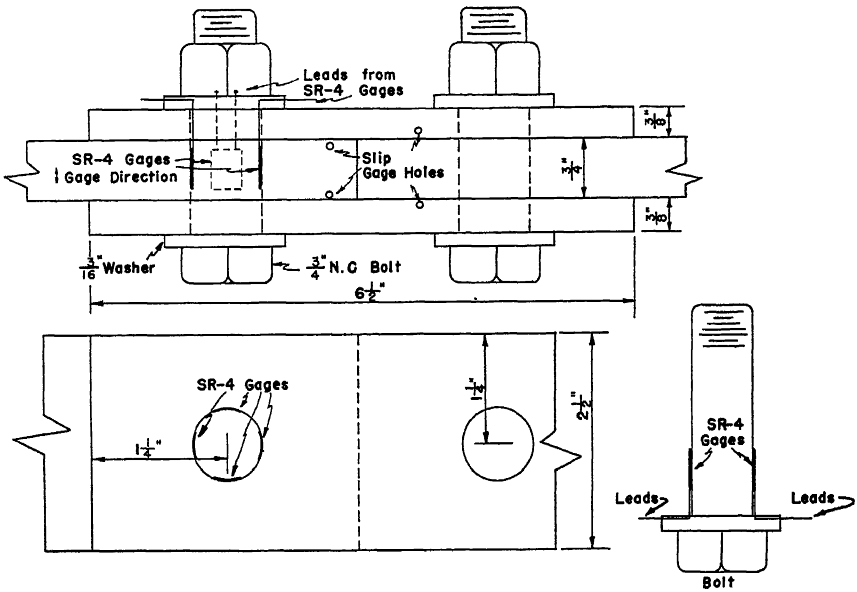


Fig. 7.—Single Bolt Butt Joint.

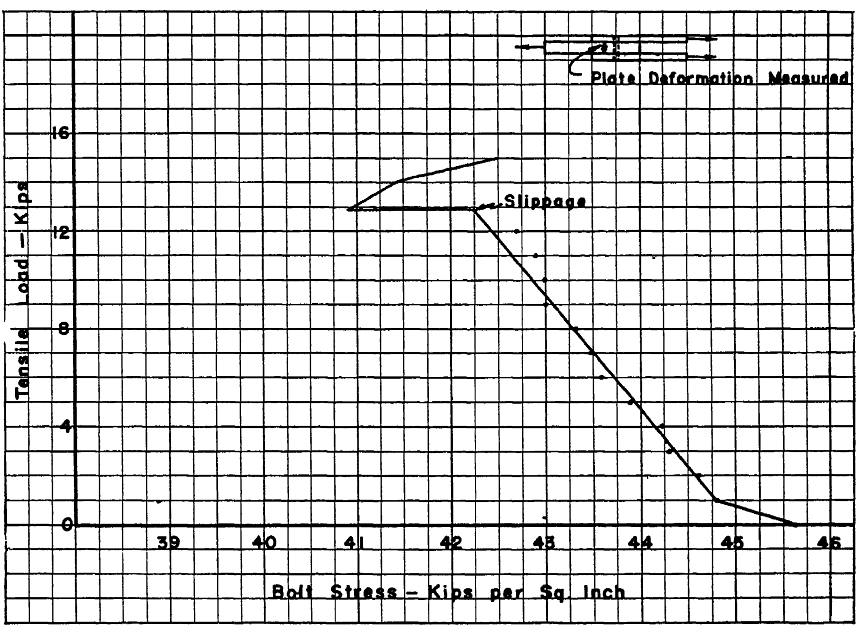


Fig. 8.—Decrease in Bolt Stress Due to Plate Tension.

of clamping force for each bolt as compared to the mean clamping force for a group of bolts was 7 percent.

To check the clamping force, total elongation readings were taken of each bolt. The drop off of bolt tension was determined in this way. The bolts were calibrated for the same grip used in the main group of tests; namely, 1½ in. A calibration curve as shown in Fig. 6 was used to relate clamping force with measured elongation. This is preferable to computation of clamping force by means of the elongation and the elastic properties of steel. Such computations require an estimate of an "effective" length and area of bolt.

Effect of Plate Tension on the Clamping Force of Bolts

The reduction of clamping force due to contraction of the plates under tension was thought to influence the slippage of a joint held entirely by friction. It was decided to determine the effect of Poisson's ratio on the clamping force before the fatigue series began. Two specimens were tested under a static load to slippage; a joint with a single bolt, and a standard fatigue specimen with nine bolts.

The specimen with the single high tension bolt was a butt joint with main plates of 2½ in. by ¾ in. by 12 in. and two strap plates of 2½ in. by ⅜ in. by 6½ in. each. A ¾-in. NC bolt with a heavy semi-finished nut was used throughout the series. Two washers, carburized to a depth of 0.032 in., were used.

Electric resistance gages of SR–4 type were placed axially on the bolt. Gages parallel to the bolt were also placed on the circumference of the hole. The single bolt butt joint is shown in Fig. 7. The bolt was first torqued to a clamping force of 20,000 lb., or a

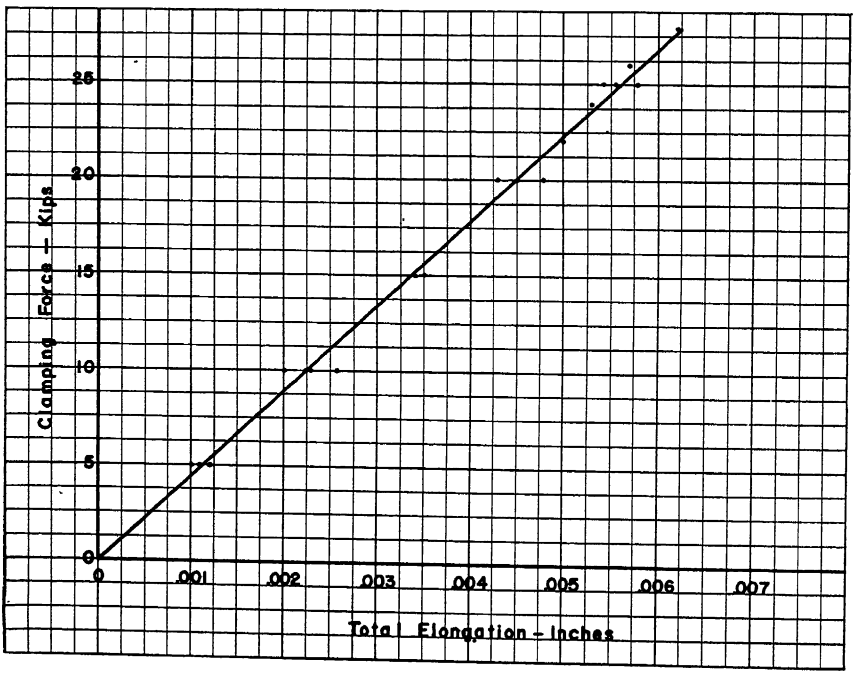


Fig. 6.—Total Elongation versus Clamping Force of Bolts as Used.

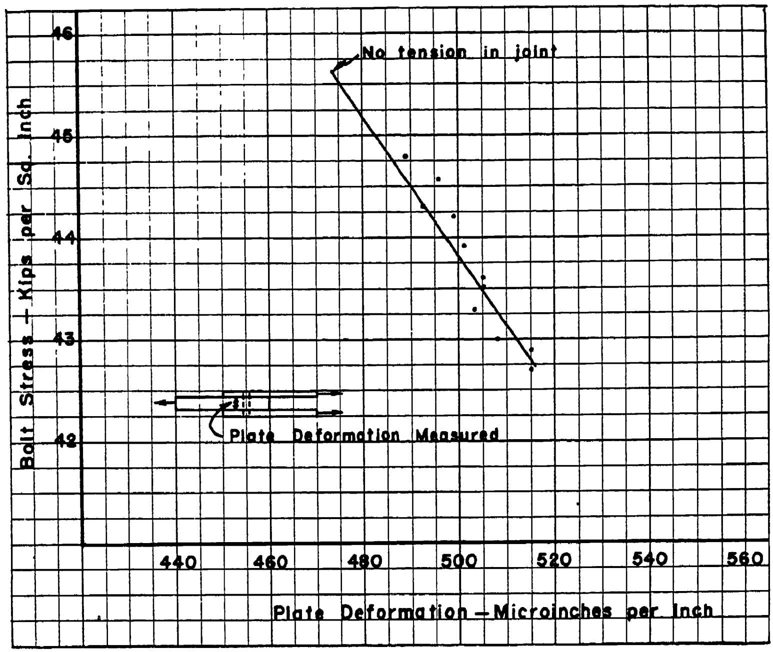


Fig. 11.—Variation of Bolt Stress with Plate Deformation.

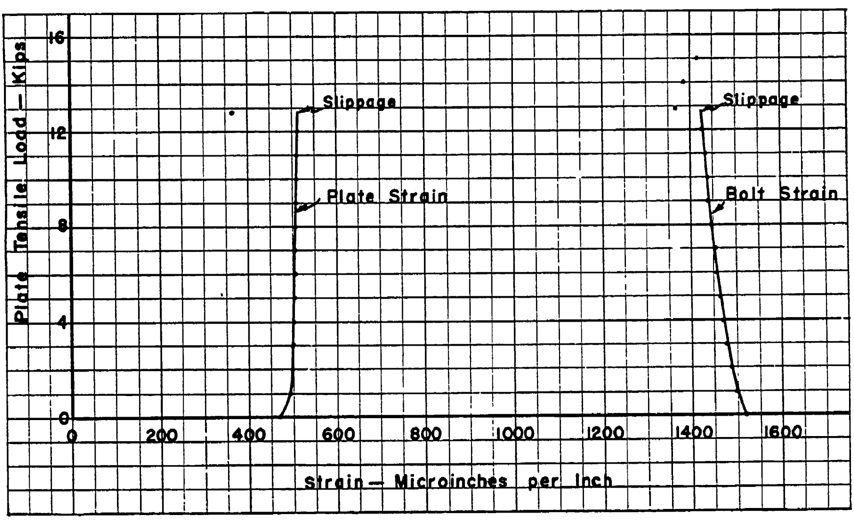


Fig. 12.—Variation in Bolt and Transverse Plate Strain Due to Axial Tension in the Plate.

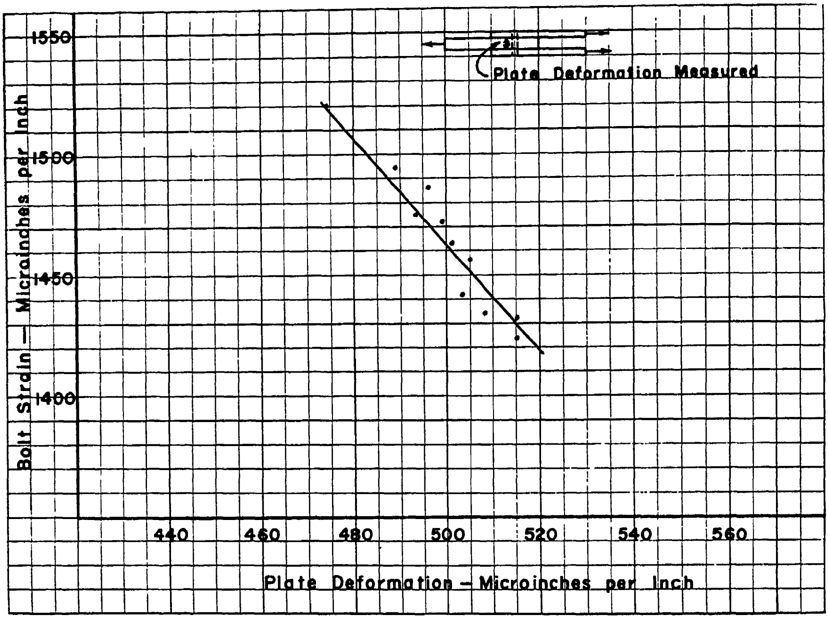


Fig. 9.—Bolt Strain versus Transverse Plate Deformation.

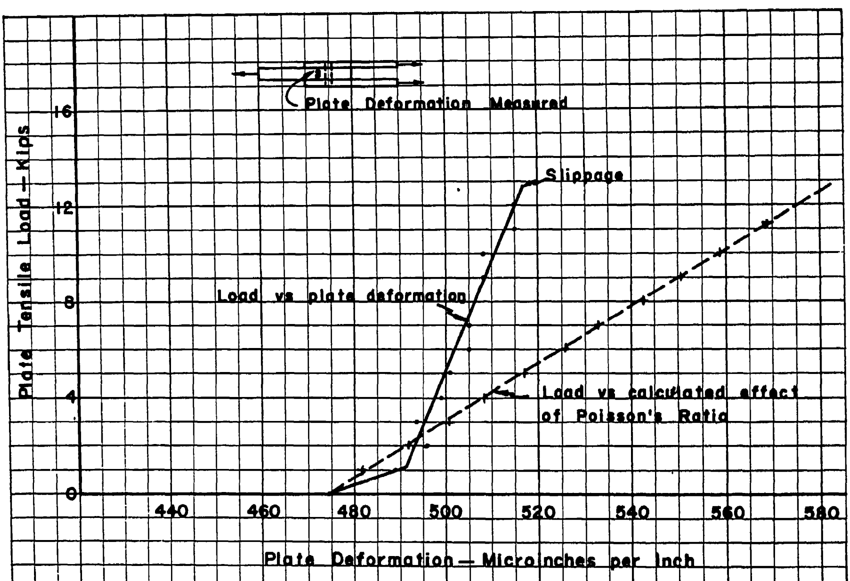


Fig. 10.—Effect of Plate Tension on Transverse Compressive Strain in the Plate, Compared with Calculated Strain Due to Poisson's Ratio.

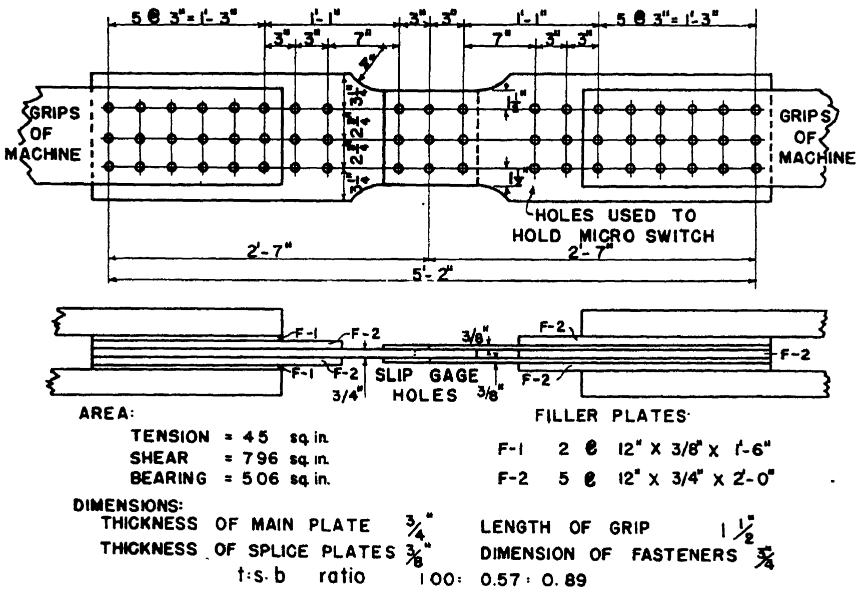


Fig. 13.—Details of Fatigue Specimens for Main Series of Tests.

The details of the main groups of specimens are shown in Fig. 13. Each specimen was a half-butt joint, having a ¾-in. main plate and two ⅜-in. splice plates. Each specimen had a grip of 1½ in. and a square pattern of nine ¾-in. diameter fasteners. The pitch, gage, and edge distance of a specimen were 3 in., 2¾ in., and 1½ in., respectively. The net area of each specimen was 4.50 sq. in., thus, resulting in a tension-shear, bearing ratio of 1:00-0.57-0.89.

The steel plates of the specimens were flame cut from larger plates and had rough edges. The plates were tested as received with no attempt to polish the specimens or to remove any of the mill scale, oil, or grease. Notches outside of the bolted joints were machined, since two riveted joints failed through such notches caused by flame cutting.

Fig. 14 shows the machines that were used in this series of tests. These machines have a capacity of ± 250,000 lb. and are of the Wilson type.[5] The load is varied by means of a double eccentric and is measured by a dynamometer or proving ring which has been calibrated for static conditions. The calibration was checked by placing a plate specimen in the machine and comparing the loads as indicated by SR-4 gages on the specimen to the loads as indicated by the dynamometer. An example of such calibration curves are shown in Figure 15. The machine is normally run at 180 cycles per minute, but an additional slow speed movement is provided for adjusting and checking the load. A micro-switch is provided to disconnect the motor at any appreciable movement due to slippage or cracking of a specimen.

The following procedure was used in conducting the fatigue tests. Dynamometer readings were taken before each specimen was placed in the machine. A 0.001-in. Federal dial gage as shown in Fig. 16a was checked against a standard gage before taking any readings. The specimen was placed in the machine and the grips were securely tightened. To obtain a balanced reversal of a small load, the connecting links of the

unit stress in the bolt shank of 45,600 psi. The specimen was then placed in a 120,000-lb. capacity Baldwin–Southwark machine. Slippage readings were taken throughout the test.

The joint was loaded in 1000-lb. increments. At each increment, slippage and strain gage readings were taken. The bolt stress decreased from 45,630 psi. at no load to 44,600 psi. at 2000 lb. of axial load. From a tensile load of 2000 lb. to slippage at 12,900 lb., the decrease of bolt tension varied directly with the increase of tensile load, as shown in Fig. 8. At slippage the clamping force was 18,050 lb. indicating a stress of 40,900 psi. This indicates a coefficient of friction of 0.357 at slippage.

The measured deformation of the plate decreased with the tensile load as shown in Fig. 9. Fig. 10 shows the variation of the bolt strain with the plate deformation. The decrease of clamping force was less than the computed effect of Poisson's ratio. The actual deformation of the plate was about 0.25 of the computed effect of Poisson's ratio. The difference between measured and computed values was partly due to the reduction of clamping force caused by the contraction of the plate. The clamping force caused the plate to be strained in compression normal to its axis. Recovery of the plates parallel to the bolt occurred when the clamping force decreased as shown in Figs. 11 and 12. The average tensile stress in the main plate adjacent to the bolt was probably less than that calculated. As this joint carried the load entirely by friction, some of the load was most likely transferred to the splice plates, before reaching the bolt.

The second joint was also a butt joint similar to the specimens used throughout the fatigue program. Nine ¾-in. high-strength bolts were arranged in a square pattern. Carburized washers and heavy semifinished nuts were standard throughout these tests. The holes were drilled 13/16 in. or 1/16 in. larger than the bolts. The plates were of structural steel; the main plate was ¾ in. thick and the two splice plates ⅜ in. The net area was 4.5 sq. in.

The bolts were torqued to the yield point, which indicates a clamping force of about 30,000 lb. per bolt, or a total clamping force of about 270,000 lb. These figures are based on torque-tension tests of the bolts. The joint was subjected to an axial load in a 1,000,000-lb. Baldwin–Southwark universal testing machine. Increments of load were chosen at 9000 lb., or 2000 psi. based on the net area. Slippage occurred at 171,000 lb. For the range of zero load to slippage, the average decrease in length of the bolts was 0.012 in. This indicates a decrease in clamping force of 3800 lb. per bolt. The clamping force at slippage is computed at 235,800 lb. A coefficient of friction of 0.36 is indicated by these figures.

After slippage had occurred, relaxation tests of the bolts were made. A residual clamping force of 207,000 lb. was indicated by these tests.

Fatigue Tests

Description of the Fatigue Tests

This section deals with the fatigue tests of typical joints and constitutes a report on the major phase of the investigation. Tests were made to determine the fatigue strength of three groups of structural joints and of a special group of bolted joints. The main series of joints were fabricated with various types of fasteners; namely, cold-driven rivets, hot-driven rivets, and bolts. All joints were subjected to a reversed cycle of fatigue loading; that is, from a tension to an equal compression. This cycle was selected since it is usually the most severe type of loading in fatigue. Each group of joints was tested in triplicate at a cycle of ± 20,000 psi. and a cycle of ± 18,000 psi. as based on the net area of each specimen. Tests were also made at ± 15,500 psi. when additional specimens were available.

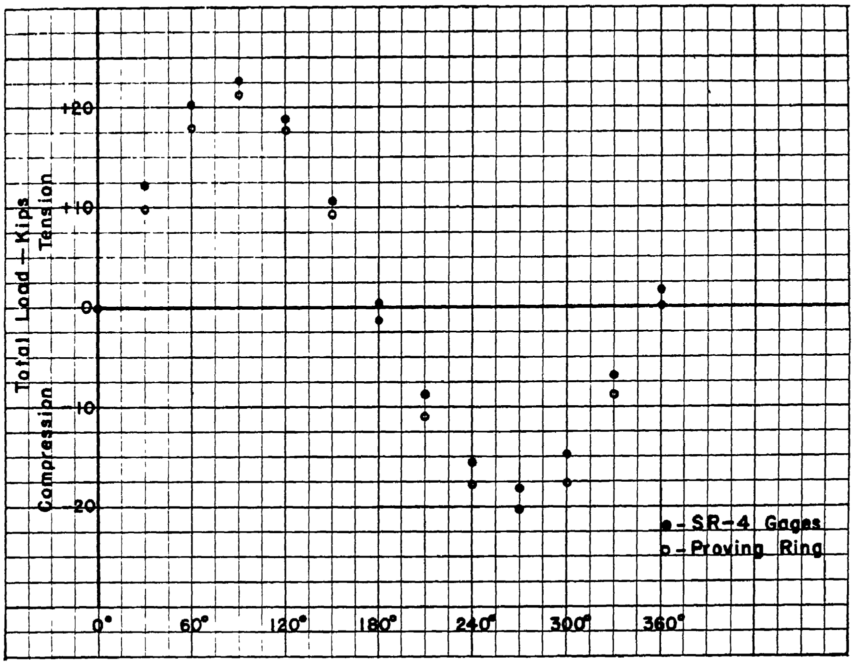


Fig. 15 —Calibration of Fatigue Machine.

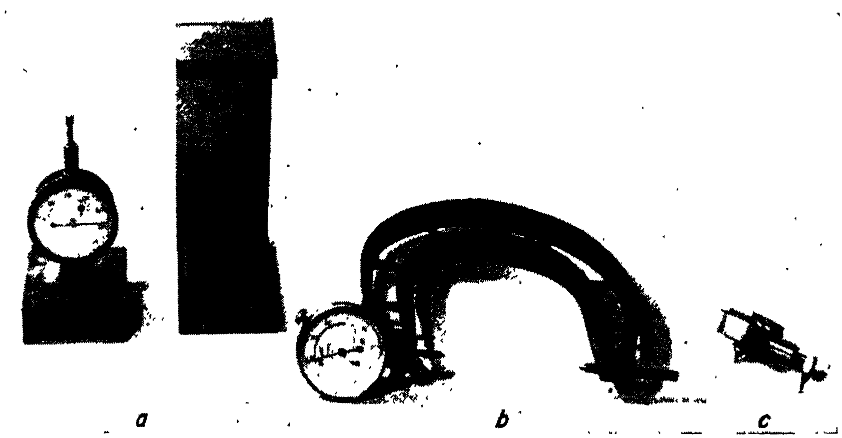


Fig. 16.—(a) Instrument Used to Measure Deflection of Proving Ring Mounted in Fatigue Machine; (b) Micrometer Type Extensometer Used to Measure Total Change in Length of the Bolts; (c) Dial Gage Used to Measure Slippage.

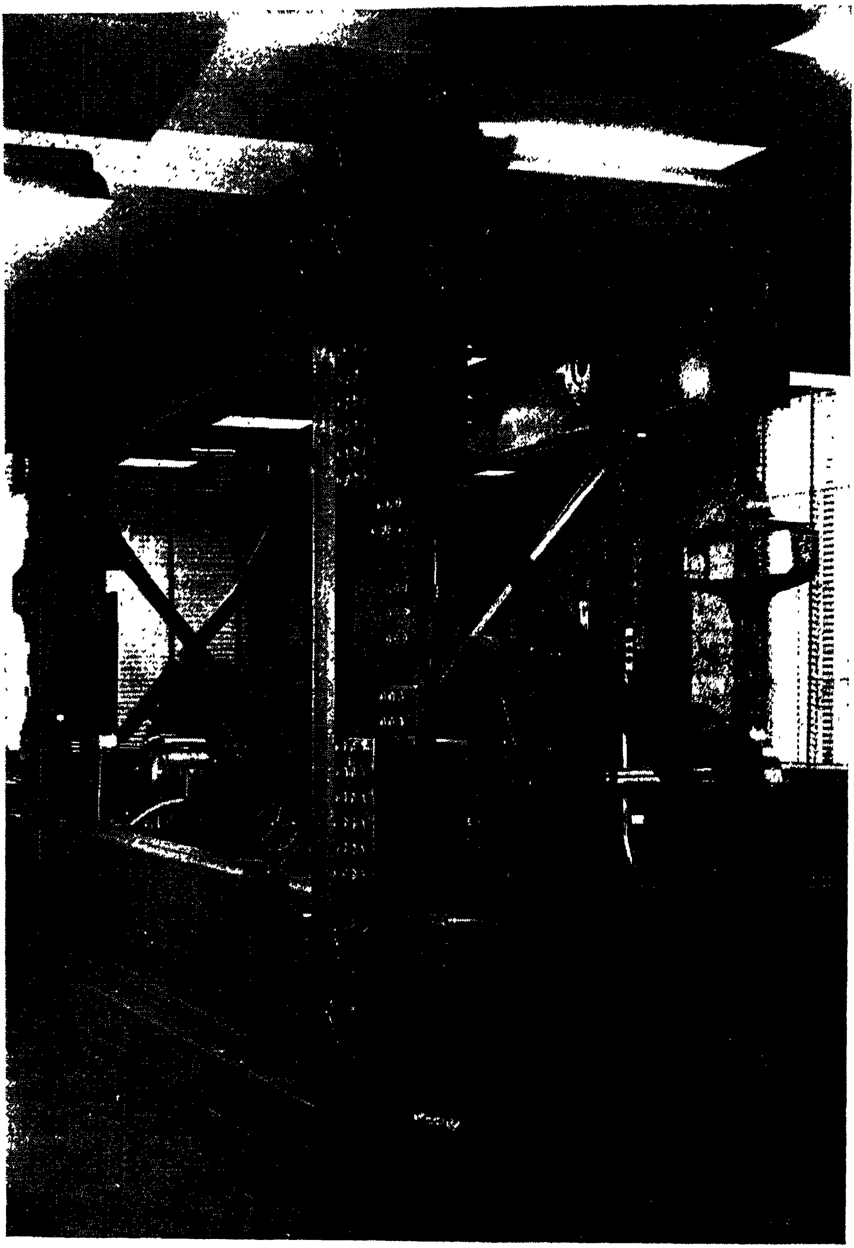


Fig. 14.—The 250,000-lb. Fatigue Machine Used in These Tests.

test results were converted by means of computations to an indicated fatigue strength at 2,000,000 cycles of fully reversed loading. The indicated fatigue strengths were obtained through the following formula:

$$S_{2,000,000} = S_t \left[\frac{\text{cycles to failure}}{2,000,000} \right]^n$$

where

$S_{2,000,000}$ is the fatigue strength at 2,000,000 cycles of reversed loading,
S_t is the fatigue stress at which the specimen was tested,
and n is an empirical coefficient

Since an insufficient number of tests was made to determine the value of n, a value of n equal to 0.1 was used as previously determined by W. M. Wilson[6] in tests of similar joints.

A noticeable bending of the splice plates was observed for specimen C–10. This bending indicated an eccentricity of the joint caused by unequal filling of the holes. Such eccentricity was also indicated by the slippage readings of specimens C–5 and C–8. The method of driving seemed to completely fill the holes on the side under the driven head. The initial slippage readings on this side varied from 0.0 to 0.0015 in. However, the holes on the side under the manufactured head seemed to be but partially filled. The initial slippage readings varied from 0.001 in. to 0.006 in. The eccentricity seemed to influence the early failure of the specimens. In addition, there was an appreciable difference between the slippage at both ends of specimen C–5. The effect of the eccentricity can be especially noted by the positions of failure as indicated in Table 2. In six of the nine specimens failure occurred in the splice plate rather than in the main plate. This type of failure is indicated in Fig. 17. Only two out of the other series of 15 fatigue specimens failed in the splice plates. The slippage throughout a joint was not uniform along the length of the joint and the history of the slippage varied during the conduction of a test. An example of the variations in slippages are given in Table 3 for specimens C–11 and C–12.

Specimens C–6 and C–7 failed through notches in the plate due to flame cutting of the plates. The notch in each case occurred at the curve between the straight sections of the main plate as shown in Fig. 18. The fatigue strength of these joints would probably have been higher were it not for these irregular notches.

Fatigue Tests of Joints Fabricated with Hot-Driven Rivets

Six structural joints fastened with hot-driven rivets were tested in fatigue to failure. The rivets for these specimens had button heads and were intended to comply with ASTM specifications A–141. The rivets were driven with a 47-ton Shepard pinch bug type of machine. Three joints were tested at a stress of approximately $\pm$ 20,000 psi. and three at $\pm$ 18,000 psi. All specimens failed at the lowest row of rivets in the main plate, as shown in Fig. 19, except the first specimen which failed in a similar position in the splice plate. The average of the computed fatigue strengths of these specimens was $\pm$ 15,820 psi. at 2,000,000 cycles of loading. Table 4 summarizes the results of the fatigue tests of joints fabricated with hot-driven rivets.

The slippage was quite large at the beginning of each test except for specimens A–9 and A–10. It decreased to a small amount during a test and at failure consisted mainly of the differences between strains of the plates. Specimen A–7, however, had a high initial slippage which increased in value during the test. This specimen was hot to the touch throughout the test, although no overheating occurred.

machine were adjusted to the lengths of a particular specimen. The eccentric was then set to obtain the desired range of loading. The links were finally adjusted for a full reversal of load. The revolution counter was set at zero, and the micro-switch was adjusted. Slippage readings were taken. The machine was then started and run for a short period. At the end of this period, the load was checked, and slippage readings again were taken. In addition, a check was made after a few hours of testing. While the test was being conducted, the load and slippage were checked in the mornings and the evenings.

In the case of the bolted joints, elongations of the bolts were measured at least once a day. These readings were made by means of a 0.001-in. Federal dial gage mounted in a frame as shown in Fig. 16b.

On each edge of a specimen, readings of the slippage between plates were taken at the elevation of the middle row of rivets. The two longitudinal edges of the specimens were designated east and west. Gage holes were drilled into the edges of the main plate and also the splice plates. The slippage readings were made with a 0.001-in. Federal dial gage as shown in Figure 16c.

Fatigue Tests of Joints Fabricated with Cold-Driven Rivets

Nine joints were fabricated with cold-formed, cold-driven rivets and were tested in fatigue. An 80 ton Hanna yoke machine, air driven with a controlled pressure of 33 tons was used to drive the cold-formed, cold-driven rivets. The manufactured heads of the cold-driven rivets were of the button type; the driven heads were flat with a minimum height of 3/16 in. and a minimum diameter of 1⅛ in.

Table 2 summarizes the results of fatigue tests on joints fabricated with cold-formed. cold-driven rivets. The average of computed fatigue strengths for the entire series is ± 14,700 psi. at 2,000,000 cycles. Since all tests were conducted at different ranges of stress, it is difficult to obtain a direct comparison of the fatigue strength of the various joints. For convenience in comparing the fatigue strength of the joints, the

TABLE 2.—RESULTS OF FATIGUE TESTS ON JOINTS FABRICATED WITH COLD-FORMED COLD-DRIVEN RIVETS

Spec No.	Cycles to Failure	Max. Axial Stress KSI	Shear Stress KSI	Bearing Stress KSI	Fatigue Strength 2 x 10^6 Cycles	Slip - Inches x 1000								Remarks
						Original				Final				
						*NE	NW	*SE	SW	*NE	NW	*SE	SW	
C-4	183,196	±20.0	±11.4	±17.8	15,730									Splice plate failed under manuf. head.
C-5	40,295	+21.8 -23.4	+12.4 -13.3	+19.4 -20.8	15,300	6.0	5.0	1.5	2.0	6.5	5.0	1.5	2.0	ditto Main plate failed.
C-6	163,383	+20.7 -20.0	+11.8 -11.4	+18.3 -17.8	15,300	.5	0	1.5	.5	4.0	3.0	5.0	3.0	Main plate—bad inclusion.
				AVERAGE	15,600									
C-7	342,867	±18.0	±10.3	±16.0	15,100	2.0	.5	.5	.5	2.0	1.5	1.5	1.0	ditto Main plate—bad inclusion.
C-8	198,901	±18.0	±10.3	±16.0	14,300	3.0	0	2.0	0	4.0	0	3.5	0	Splice plate—manuf. head.
C-9	317,914	±18.0	±10.3	±16.0	15,000	2.0	.5	1.0	1.0	3.5	0	1.0	0	ditto Splice plate—driven head.
				AVERAGE	14,800									
C-10	442,996	+15.9 -15.5	+ 9.1 - 8.8	+14.2 -13.8	10,900	1.5	2.5	.5	0	1.5	2.0	.5	0	ditto Splice plate—manuf. head.
C-11	1,257,280	±15.5	± 8.8	±13.8	14,800	2.5	0.5	1.0	0	2.0	0	3.0	.5	ditto Splice plate—manuf. head.
C-12	1,441,131	+15.5 -15.5	± 8.8	±13.8	15,000	1.0	1.0	0	0	4.0	1.0	5.0	0	Splice plate at grip holes—manuf. head.
				AVERAGE	13,600									
				AVERAGE OF SERIES	14,700									

*NE & SE readings are those on the side of the driven heads.

TABLE 3.—AN EXAMPLE OF THE VARIATIONS IN SLIPPAGES FOR SPECIMENS C-11 AND C-12.

Specimen C-11

		Slip - Inches x 1000			
Cycles	Row	NE	NW	SE	SW
0	Top	0.5	2.5	0.25	1.0
	Mid.	0.25	1.5	0.25	1.0
	Bot.	1.0	3.0	0	1.0
40,104	T	0.5	4.0	0	1.5
	M	0.25	3.0	1.0	1.5
	B	1.0	3.0	0.5	1.0
68,554	T	0.5	3.5	0	1.5
	M	1.0	2.0	1.0	2.0
	B	1.0	3.0	0.5	1.5
235,427	T	0.5	3.0	0	1.0
	M	0	1.5	1.0	1.0
	B	0.25	2.5	0	0.5
326,977	T	0	2.0	0	1.0
	M	0	1.5	1.0	0.5
	B	0.25	2.5	0	0.25
490,591	T	0.5	3.0	0	1.0
	M	0	2.0	1.0	1.0
	B	0.5	2.0	0	0.5
555,450	T	0.25	3.0	0	1.0
	M	0	1.5	0.5	1.0
	B	0.25	2.0	0	0.25
739,146	T	0.25	3.0	0	1.5
	M	0	2.0	1.0	2.0
	B	0.5	2.5	0.5	1.0
968,411	T	0.5	3.0	0	2.0
	M	0.25	2.0	1.0	2.0
	B	1.0	2.0	0	2.0
1,042,793	T	0.25	3.0	0	2.0
	M	0	2.0	1.0	2.0
	B	1.0	2.5	0	2.0
1,211,660	T	0.25	3.0	0	3.0
	M	0	2.0	0.5	3.0
	B	0.25	2.0	0	2.5

Specimen C-12

		Slip - Inches x 1000			
Cycles	Row	NE	NW	SE	SW
0	Top	3.0	1.0	1.0	2.0
	Mid.	1.0	1.0	0	0
	Bot.	0.25	0.25	0.25	0.25
32,745	T	2.0	2.0	1.5	3.0
	M	1.0	1.0	0	0
	B	0.25	0.25	0.5	1.0
69,256	T	3.0	1.0	1.0	2.0
	M	1.0	0.5	0	0
	B	0.5	0.5	0.5	0.25
139,204	T	3.0	1.0	1.0	2.0
	M	1.0	0.5	0.5	0
	B	0.5	0.5	0.5	0.25
235,327	T	2.0	2.0	1.5	1.0
	M	1.0	1.0	0.25	0
	B	0.50	0.5	0.5	0.5
324,214	T	2.0	2.0	1.0	1.5
	M	0.25	0.25	0.25	0.5
	B	0.25	0.5	0.5	0.25
407,043	T	3.0	2.5	1.5	2.5
	M	1.0	0.5	0	0.5
	B	0.5	1.5	0.5	0.5
641,144	T	2.0	4.0	0.5	2.0
	M	0.5	3.0	0.25	0.5
	B	0.5	3.0	0.25	0.5
876,760	T	2.0	5.0	0.5	3.0
	M	1.5	4.0	0	1.0
	B	1.0	4.0	0	1.5
932,193	T	2.0	5.0	1.0	1.5
	M	5.0	5.0	0.5	1.0
	B	5.0	5.0	0.25	1.0
1,204,962	T	2.5	5.0	1.0	2.0
	M	1.0	5.0	0.25	1.0
	B	5.0	4.0	0.25	1.0
1,272,439	T	1.5	5.5	1.0	3.0
	M	1.0	4.0	0.25	5.0
	B	1.0	5.0	0.25	1.0

Fatigue Tests of Bolted Joints

Nine structural joints fastened with bolts were tested in fatigue to failure. The bolts were made of 1038 steel and were regular, semifinished, hexagonal, ¾-in. high-tensile bolts with 10 threads per inch. These bolts were cold-headed and were quenched and tempered and had rolled threads. Hardened washers carburized to a depth of 0.030 in. were used with heavy, semi-finished, hexagonal, milled-from-bar nuts. Table 5 summarizes the results of joints fabricated with high-tensile bolts.

All bolts in specimens D–7 and D–8 were torqued above their yield strength to obtain the maximum clamping force. In these joints a greater drop off in clamping force was expected during testing than for joints still resisting slippage, but with a clamping force below yield. Also, if the bolts were to fail in fatigue due to the effect of Poisson's ratio on changes in clamping force, failure would most likely occur with the bolts stressed above the elastic limit. For the two joints having bolts torqued above the yield strength, no excessive drop-off in clamping force was recorded, nor was there any indication of damage to the bolts. Both joints were tested at a cycle of ± 20,000 psi. Specimen D–8 failed through the lowest row of bolt holes. Specimen D–7 failed at the row of holes where the micro-switch was attached. The net area of this section was

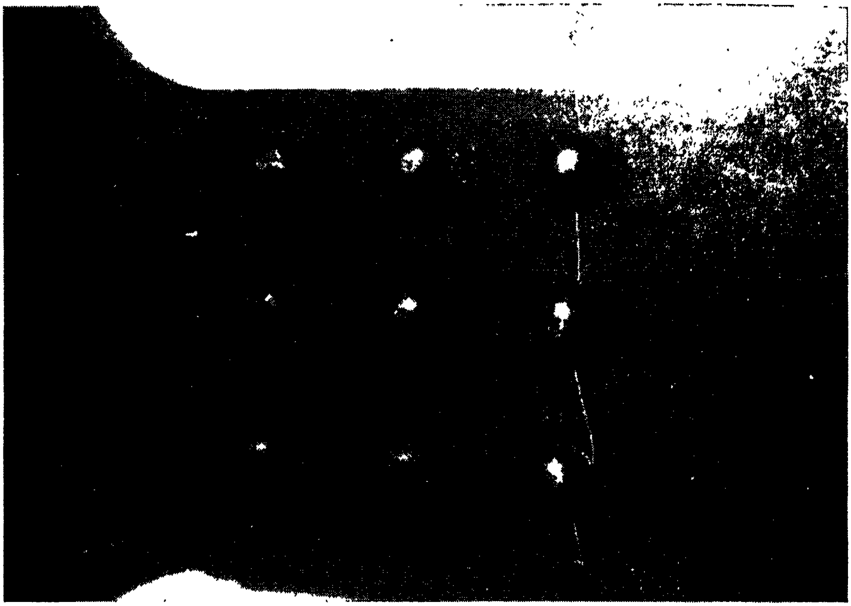


Fig. 17.—Typical Splice Plate Failure Under the Manufactured Head of Cold-Driven Rivets. (Specimen C–10)

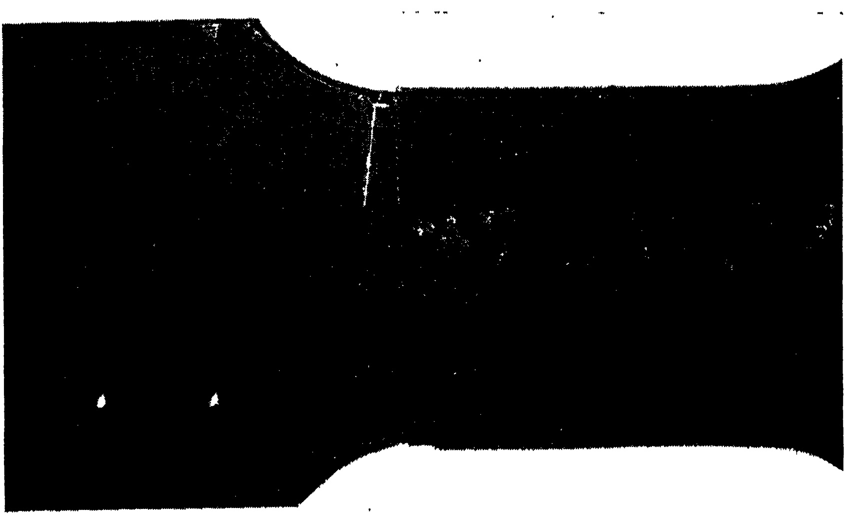


Fig. 18.—Failure of a Fatigue Specimen in a Notch That Was Due to Flame Cutting the Specimens. (Specimen C–7)

TABLE 4.—RESULTS OF FATIGUE TESTS OF JOINTS FABRICATED WITH HOT DRIVEN RIVETS

Spec. No.	Cycles to Failure	Max. Axial Stress KSI	Shear Stress KSI	Bearing Stress KSI	Fatigue Strength 2 x 10⁶ Cycles	Slip - Inches x 1000 Original NE	NW	SE	SW	Final NE	NW	SE	SW	Remarks	
A-7	228,348	±20.0	±11.3	±17.8	16,120	6.0	6.0	8.0	8.0	8.0	9.0	12.0	13.0		Splice Plate
A-8	200,931	+20.4 -20.7	+11.6 -11.8	+18.2 -18.4	16,300	5.0	5.0	2.5	1.5	1.0	1.0	1.0	1.0	ditto	Main Plate
A-9	197,744	+20.1 -20.6	+11.5 -11.7	+17.9 -18.3	16,180	0	0	2.0	2.0	.25	.25	2.0	1.5	ditto	Main Plate
		AVERAGE FATIGUE STRENGTH			16,200										
A-10	236,219	+18.3 -18.0	+10.4 -10.3	+16.3 -16.0	14,800	.25	0	.25	0	.25	0	.25	0	ditto	Main Plate
A-11	489,995	±18.0	±10.3	±16.0	15,650	3.0	0.5	2.5	2.0	1.0	1.5	1.0	1.0	ditto	Main Plate
A-12	562,927	±18.0	±10.3	±16.0	15,860	4.5	5.5	4.0	3.5	1.0	1.5	1.0	0.5	ditto	Main Plate
		AVERAGE FATIGUE STRENGTH			15,430										
		AVERAGE OF SERIES			15,820										

TABLE 5.—RESULTS OF FATIGUE TESTS OF JOINTS FABRICATED WITH HIGH TENSILE BOLTS

Spec No.	Cycles	Max. Axial Stress KSI	Shear Stress KSI	Bearing Stress KSI	Fatigue Strength 2 x 10⁶ Cycles	Slip In. x 1000	Total Clamping Force Orig. Kips	Final Kips	Change of Clamping Force Kips	Torque Applied Ft/Lbs.	No. of Bolts	Failure	
D-6					TENSION TEST TO SLIPPAGE								
D-7	338,903	±20.0	±11.4	±17.8	16,800	1.0	Above yield 270.0	244.8	25.2	330	9		Main Plate
D-8	574,648	±20.0	±11.4	±17.8	17,700	0.25	Above yield 270.0	225.0	45.0	330	9		Main Plate
D-9	360,686	±20.3	±11.6	±18.1	17,300	0.25	217.8	200.7	17.1	240	9		Grip Hole Main Plate
D-10	1181,270	+18.6 -18.8	+10.6 -10.7	+16.6 -16.7	17,700	0.25	173.7	160.2	13.7	240	9		Main Plate
D-11	1061,106	±18.0	±10.3	±16.0	17,000	0.25	220.5	181.8	40.3	240	9		Main Plate
D-12	1400,508	±18.0	±10.3	±16.0	17,400	0.25	253.8	230.4	23.4	310	9	ditto	Main Plate
D-13	326,418	+20.3 -20.5	+13.0 -13.1	+20.3 -20.5	17,350	0.5	140.0	140.0	0	240	8		Grip Holes Splice Plate
D-14	810,536	+20.3 -20.0	+13.0 -12.8	+20.3 -20.0	18,400	0.5	152.0	161.6	9.6	240	8		Main Plate
D-15	1640,916	±15.0	±8.6	±13.3	14,800	1.0	193.5	171.0	22.5	240	9	ditto	Main Plate

AVERAGE 17,200 Including Specimen D-15
17,500 Neglecting Specimen D-15

6.5 sq. in., as compared to a net area of 4.5 sq. in. for the joint. In succeeding tests, bolts were placed in all holes of the grip and the grips were clamped tightly. Two other specimens, D-9 and D-13, failed in the grips of the specimen. A high clamping force could not be developed at the holes where the micro-switch was attached. The small amount of slippage of D-7 and all of the succeeding specimens was particularly noted. Although the holes were 1/16 in. greater in diameter than the bolts, in no case was the measured slip more than 0.001 in. This measured value can be attributed almost entirely to strain.

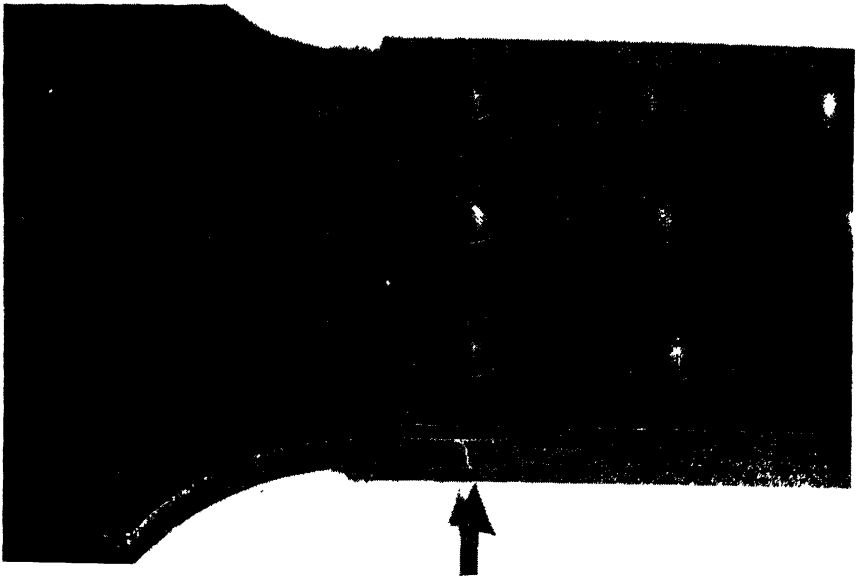


Fig. 19.—Typical Failure of Specimens Fabricated with Hot-Driven Rivets. (Specimen A–10)

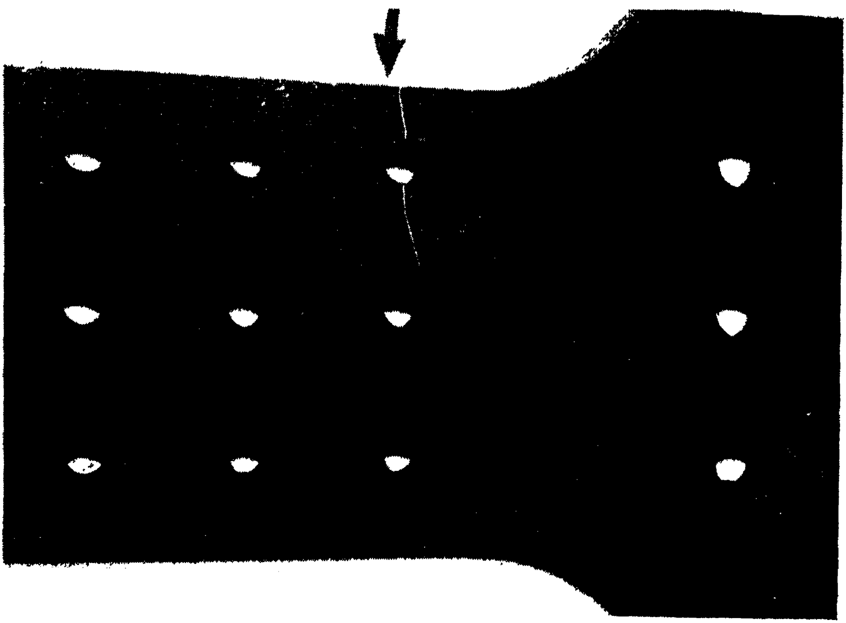


Fig. 20.—Location of Failure in Joints Fabricated with Bolts When the Failure Occurred Within the Joint. (Specimen D–8)

The total decrease of clamping force was 25,200 lb. for specimen D–7 and 45,000 lb. for D–8. If the clamping force per bolt was 30,000 lb. at yield, as determined from torque-tension tests, the total initial clamping force on the joint was 270,000 lb. The decrease in clamping force was about the same for each bolt of specimen D–7. The decrease for seven out of nine bolts of specimen D–8 was the same and approximately equal to the decrease obtained in specimen D–7. For the other two bolts a large decrease occurred between 26,000 cycles and 192,000 cycles of loading. Cracks developed at these bolt holes and were noticeable at 574,648 cycles. At no time was there a tendency for the applied load to decrease in value. Fig. 20 shows the failure that occurred within the bolted joint.

The bolts in specimen D–9 were torqued to 240 ft.-lb. A total clamping force of 217,800 lb. was indicated. The specimen was tested at a cycle of ± 20,300 psi. The main plate failed at the lowest row of holes in the grip.

Specimens D–10 and D–11 were tested at a reversed cycle of ± 18,000 lb. The bolts in these specimens were torqued to 240 ft.-lb. Specimen D–10 failed in the main plate at the lowest row of holes in the joint. Specimen D–11 failed just below the joint at a gross section of the specimen. The clamping force of the bolts in the lowest row of holes of D–10 was very small in value. Fig. 21 shows the location of failure occurring in the gross section of the main plate.

Specimen D–12 was tested at the same cycle of loading as D–10 and D–11. The bolts were torqued to 310 ft.-lb. and were just below yield point. The total clamping force was 253,800 lb. giving an average of 28,200 lb. per bolt. This specimen also failed in the gross section of the main plate just below the joint.

The center bolt of the square pattern was not used in specimens D–13 and D–14. The torque was 240 ft.-lb. per bolt. These specimens were tested at a cycle of ± 20,000 psi. These specimens behaved similarly to the specimens with nine bolts. The t–s–b ratio was 1.0–0.64–1.0. Specimen D–13 had a low clamping force for the applied torque. It is to be noted, however, that D–13 showed no change in clamping force, whereas D–14 showed a slight increase of about 1000 lb. per bolt. This increase was quite uniform except for one bolt which had a small decrease in clamping force. Both specimens failed outside the joint. D–13 failed at the row of holes where the micro-switch was attached. D–14 failed just below the joint at a gross section of the main plate.

Specimen D–15 was tested at a reversed cycle of ± 15,000 psi. A low value of stress was chosen to determine whether any loosening of bolts occurred at the end of a considerable number of cycles. An irregular notch in the plate similar to that shown in Fig. 18 contributed to premature failure at 1,640,916 cycles.

The average value of the fatigue strength for the bolted joints was 17,200 psi. at 2,000,000 cycles of reversed loading. If specimen D–15 is neglected, the average value of the fatigue strength is ± 17,500 psi. at 2,000,000 cycles.

Special Tests—Bolted Joints

After the bolted specimens had been tested, the effects of a smaller grip and a larger ratio of pitch to thickness were studied. Four ⅝-in. plates were milled to the same shape and dimensions as the center plates of the previous specimens. Holes were drilled to match the splice plates of the main series. Only the four corner holes were filled with bolts, although all holes in the upper and lower rows had been drilled. The t–s–b ratio of these specimens was 1.0–0.64–1.80.

In general, the physical properties of the material were similar to those of the steel used in the main series. The bolting and testing procedure was the same as that used

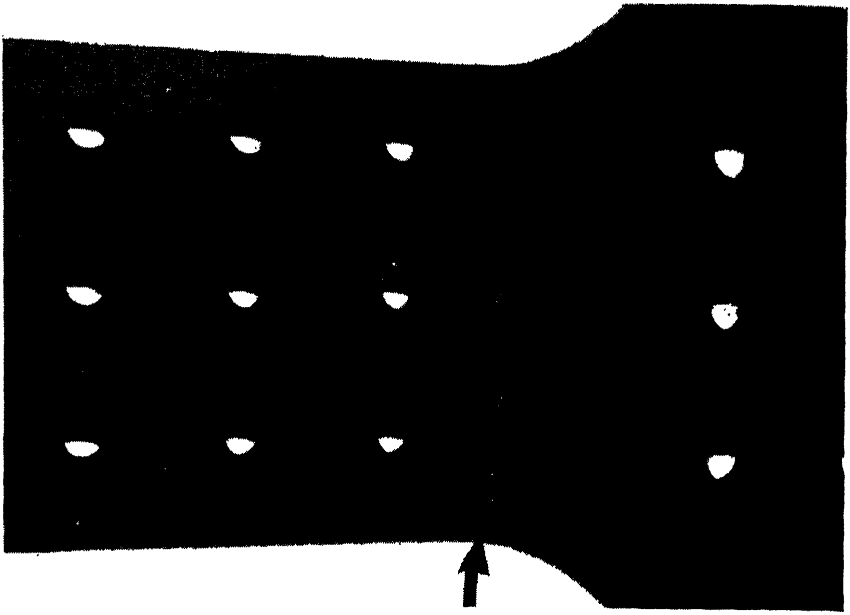


Fig. 21.—Location of Failure Occurring in Three Joints Fabricated with Bolts. (Specimen D-14)

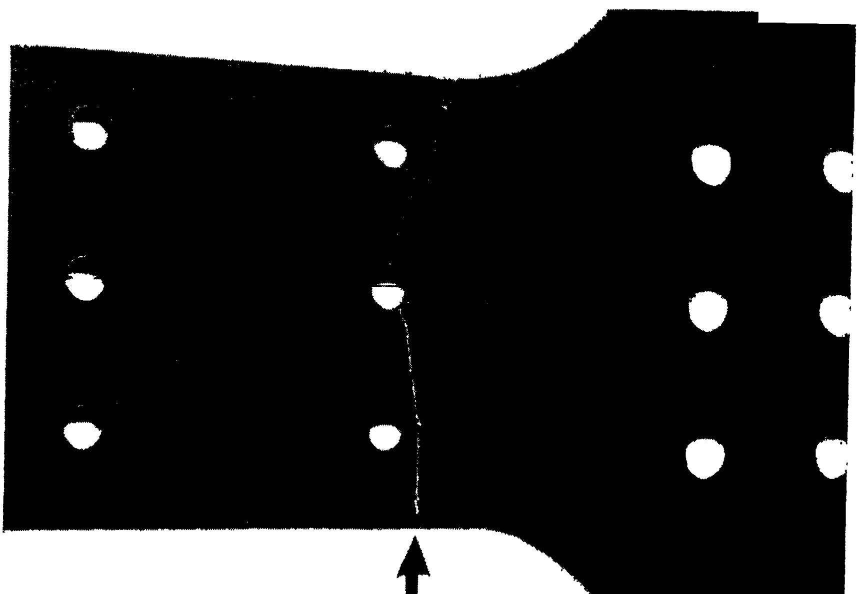
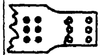


Fig 22.—Typical Failure of the Four Special Joints Fabricated with Bolts.

TABLE 6.—RESULTS OF SPECIAL JOINT FABRICATED WITH HIGH TENSILE BOLTS

Spec. No.	Tension KSI	Shear KSI	Bearing KSI	Cycles	Fatigue Strength 2×10^6 Cycles	Slip In. x 1000	Total Clamping Force Orig. Kips	Total Clamping Force Final Kips	Change of Clamping Force Kips	Torque Ft-Lbs.	No. of Bolts	Failure	
S-1	±20.0	±12.8	±40.0	1,240,723	19,100	1.0	85.6	80.8	-4.8	240	4		Main Plate
S-2	±20.0	±12.8	±40.0	1,637,135	19,700	1.0	95.6	74.4	-21.2	240	4	ditto	Main Plate
S-3	±20.0	±12.8	±40.0	1,318,641	19,200	1.0	104.0	90.0	-14.0	240	4	ditto	Main Plate
S-4	±16.0	±10.2	±32.0	3,607,713	17,000	0.5	104.0	94.4	-9.6	240	4	ditto	Main Plate

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previously. Table 6 summarizes the results of the special joints fabricated with high tensile bolts.

Specimens S-3 and S-4 were tested with regular nuts rather than with the heavy nuts used in all other bolted specimens. Regular nuts were used to determine their behavior with high tensile bolts in the fabrication of a joint. Because of the smaller friction area and smaller body of the nut, it was thought that a larger drop-off of clamping force might occur. No difference in behavior was noted, although for the regular nuts a larger clamping force was obtained for the same torque. This was due to the narrower width of regular nuts reducing the frictional moment on the bearing surface.

The method of failure in each specimen was the same as shown in Fig. 22. It was noted upon disassembling the specimens that the crack was largest at the center hole having no bolt. The crack apparently propagated in both directions from this hole toward the filled holes and dipped downward and away from the latter holes. In no case did the crack extend through any of the holes with bolts. The machine was stopped as soon as the crack had extended to one outer edge of the specimen. It was observed that a crack was also nearing the opposite edge. This indicated that in each case the crack had started at the center hole.

Specimen S-4 was tested at a small range of reversed cycle of loading. Failure occurred at 3,607,713 cycles. No greater reduction in clamping force was observed for S-4 than for the other three specimens.

The fatigue strength of this series was considerably higher than that of the regular series. The conditions of the edges may have influenced the indicated fatigue strength. The edges of the special series were machined and very smooth as compared to those of the regular series. The average fatigue strength of the special specimens was ± 18,800 psi. at 2,000,000 cycles of loading. No slip above 0.001 in. was observed in any of these specimens.

Discussion of the Tests

The average fatigue strength of the joints with cold-driven rivets was ± 14,700 psi. at 2,000,000 cycles of loading, with hot-driven rivets ± 15,820 psi., and with bolts ± 17,200 psi. The results indicate that the joints with hot-driven rivets were from 5 to 7 percent stronger than those with cold-driven rivets. In addition, the joints fabricated with bolts were from 14 to 19 percent stronger than those with cold-driven rivets, and 9 to 11 percent stronger than those with hot-driven rivets. It should be noted that the fatigue failure always occurred in the plates.

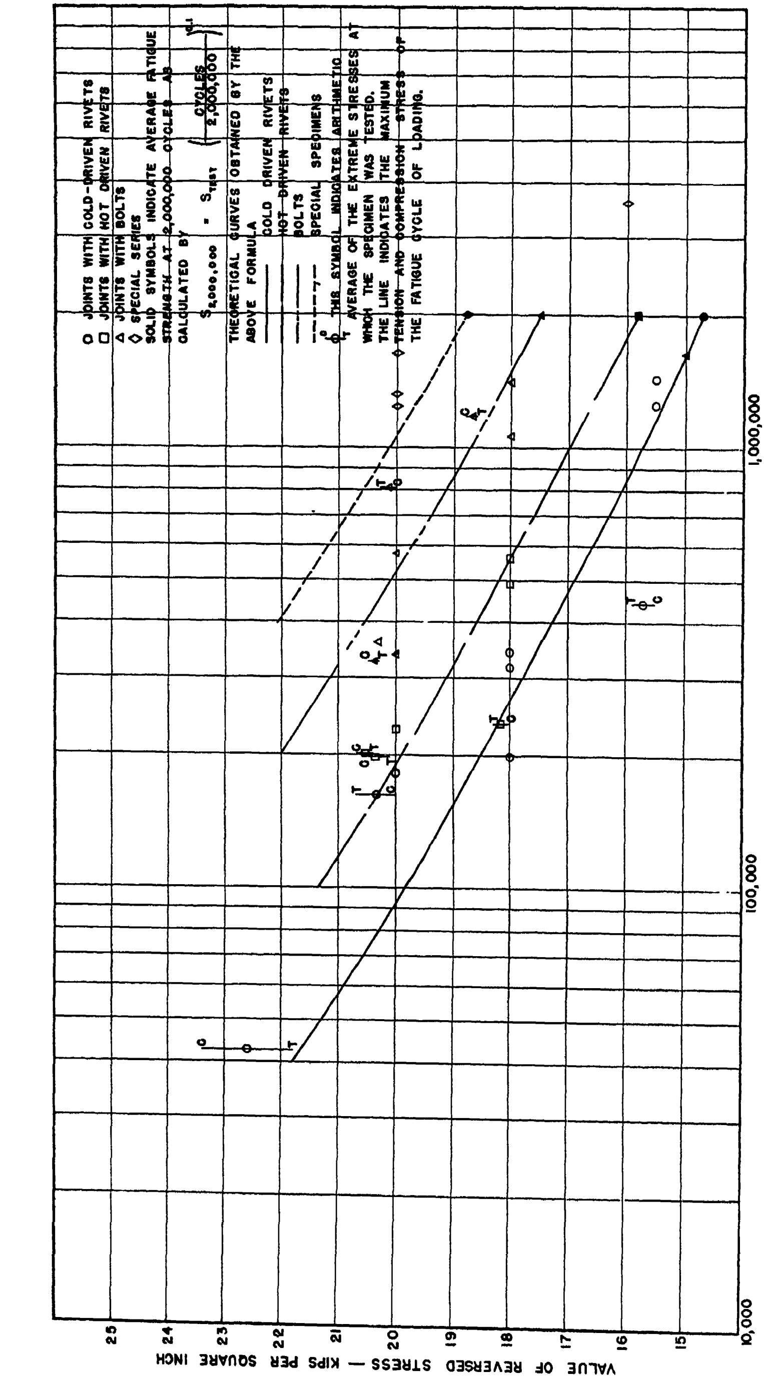

Fig. 23.—Test Results Compared to Computed S-N Curves.

It may be of additional interest that the fatigue strength of the two specimens which failed through the lower row of bolted holes was the same as for those specimens which failed outside the joint. Loss of clamping force in these two specimens seemed to affect the position of the crack but not appreciably the magnitude of fatigue strength.

As stated previously, the fatigue cracks in the special joints with bolts seemed to start in the open center hole of the main plate, as shown in Fig. 22. In every case the cracks dipped downward as they propagated toward the outer edges and extended below the holes which were filled with bolts.

In the two series of bolted specimens, initial compressive strains in the longitudinal plane of the plate were caused by the high clamping force of the bolts. Perhaps these initial strains in the immediate vicinity of the holes were large enough to minimize the concentration of tensile strain produced by longitudinal load. The gross area of the plate may thus become the critical section as a result of the initial strains influencing the fatigue strength. Additional tests are required to investigate whether fatigue failures will always occur outside of the bolted joints for large values of clamping force.

Conclusion

1. The fatigue strength of the plates was greater for the bolted joints at a 1½-in. grip than for the riveted joints. In addition, the slippage was smaller for the bolted joints. These tests indicate the possibility of accepting bolted joints for structural members subjected to reversal of load.

2. The fatigue strength was slightly greater for joints with hot-driven rivets than for joints with cold-driven rivets.

3. Joints with cold-driven rivets were subjected to more bending in fatigue than those with hot-driven rivets. This may be due to the eccentricity caused by unequal filling of holes. The type of heads used in cold-riveted construction has an appreciable effect, however, on the degree of filling. The initial slippage was greater for joints with hot-driven rivets than for joints with cold-driven rivets.

4. The change in grip from 1½ in. to 1⅞ in. had no effect on the behavior of joints with bolts.

5. A joint was fabricated with bolts torqued above the elastic limit and was found satisfactory. In this case, no greater decrease in clamping force was measured during these tests than previously. The bolts did not show signs of damage.

6. Two of the special joints were fabricated with regular nuts rather than heavy nuts. The decrease in clamping force was no greater for joints with regular nuts than for joints with heavy nuts.

7. Three bolted specimens indicated a decrease of 18 percent in clamping force during the course of the tests. For the other ten specimens the loss in clamping force ranged between 0 and 13 percent. No loosening of nuts was noted, although one specimen was subjected to more than 3.6 million cycles.

8. Static tests of joints fabricated with one bolt and also with nine bolts indicated that the coefficient of friction is approximately 0.35.

9. If sufficient clamping force is developed in the bolts of a joint, failure may occur outside of the joint. The fatigue crack may not go through holes filled with highly stressed bolts.

These variations in the fatigue strength of the different types of joints are related to the filling of the holes and the clamping force of the various fasteners. These were the only variables in the joints tested. The clamping stress as shown in Table 1 was 12,000 psi. in the hot-driven rivets and 3400 psi. in the cold-driven rivets. The clamping force of the bolts varied with a minimum of about 50,000 psi. The filling of the holes as measured by initial slippage and the diameter of the driven rivets show that the cold-driven rivets almost completely fill the holes. The hot-driven rivets have a diameter about 0.006 in. less than that of the hole. The bolts are 1/16 in. less in diameter than the holes. Fig. 23 is a comparison of the test results to the computed curves.

It is emphasized that the main series of tests were made with a grip of 1½ in. The fatigue strength of the plates may be affected by a change in grip. It is expected that the clamping force and the filling of holes will be different for the two types of rivets at other values of grip. It is also possible that the effect of clamping force for bolts may differ for various grips, although the bolted joints were tested at grips of 1½ in. and 1⅛ in. The smaller grip was represented by the four special specimens. The studies of Professor W. M. Wilson of the University of Illinois[6, 7] have indicated that the clamping force of hot-driven rivets approaches the yield strength of the material at a grip of 2 in. to 3 in.

In addition, the comparative filling of holes for cold-driven rivets may vary at different grips. Although no appreciable clamping force can be expected for cold-driven rivets, the fatigue strength may be affected by variations in filling of holes. Due to the unequal filling of holes, an appreciable eccentricity was observed in all joints having cold-driven rivets. The effect of this unequal filling is indicated by the failure in a splice plate by six of nine specimens. Two of the three specimens that failed in the main plate cracked through an irregular notch. Only 2 of the other 19 specimens failed in the splice plate.

Five specimens with cold-driven rivets failed in the splice plate adjacent to the manufactured head of the rivet as shown in Fig. 17. Only one specimen failed in the splice plate adjacent to the flat or driven head of the rivet. The average diameter of the rivet near the driven head was 0.832 in.; and near the manufactured head, 0.813 in. These diameters are to be compared with the 13/16 in. diameter specified for the drilling of holes. This indicates that the driven end of the rivet overfilled the hole, but the end adjacent to the manufactured head barely filled the hole. This difference is also indicated by the slippage readings of the cold-driven riveted joints tested in fatigue as shown in Table 2. The over-filling of the holes in the splice plate would minimize the elongation of the hole during the tension cycle and would produce a more uniform distribution of load in bearing. Although slippage of the joint may decrease the load on the splice plate adjacent to the manufactured head of the rivets, the eccentricity of the load, and the incomplete filling of holes seems to contribute to a lower fatigue strength.

A crack extended through a filled hole in only two bolted specimens tested in fatigue. In all other bolted specimens of the main series, failure was through the grip holes or through the gross section of the plate. Three specimens failed through the holes of the grip, and four failed through the gross area of the plate. The gross area and the area through the grip holes were 6.4 sq. in., whereas the net area of the plate was 4.5 sq. in. Specimens D-8 and D-10 failed through the lowest row of bolt holes. Succeeding measurements indicated that the bolts in this row had either a low initial clamping force or had lost a large portion of the clamping force soon after the fatigue test began.

It should be noted that the frictional force between plates distributes part of the load to the splice plates before the first row of holes is reached. Thus the computed stress is probably greater than the actual average stress at the net area of the plate.

Test of Three Methods of Attaching Tie Plates*

Report of an Investigation Conducted by the Pennsylvania Railroad that Embraced Cut Spikes, Screw Spikes and Through Bolts As Well As Flat and Wave Bottom Plates

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This is the final report on an investigation known as M. of W. Test No. 11, Various Methods of Attaching Tie Plates to Ties. The test material included:

1. Four bolts per plate extending through the tie plate and the tie with headlock washers on the underside of the tie and insulated to prevent interruption of signaling.
2. Four screw spikes per plate without spring washers.
3. Two cut spikes per plate of the standard design used in 1928–29 (not full throated).

Cut spikes of same design as No. 3 above were used for rail holding in all methods of plate attachment.

The test was authorized March 1, 1929, and progress reports were made November 24, 1933 and January 29, 1938.

It was desired to determine by observations and measurements the possible economy, merit, and efficiency of an arrangement of through bolts and also screw spikes, compared with the usual cut spikes in preventing or retarding plate penetration. Other possible benefits should be increased tie life, reduced maintenance cost, and better riding track with tie plates securely fastened and maintained tight to avoid movement and abrading action of the tie plates under traffic.

The test was conducted on sharp curves and tangents of Middle Division No. 1 track between Spruce Creek and Union Furnace, Pa., under traffic which normally amounts to 70 to 75 million gross tons annually.

Description

For use in the test, 2420 size 5 best grade creosoted red oak ties, 7 in. by 9 in. by 8 ft. 6 in. were selected and prebored at the Orrville, Ohio, tie treating plant. Tie plates, bolts, screw spikes, and other fittings, except fiber insulation, were purchased from the Bethlehem Steel Company and shipped to the Orrville plant where all material was assembled and plates applied.

All tie plates were of the heavy duty type 130-lb. PS, double-shoulder, 7 in. by 14 in., specially drilled or punched for the various methods of attachment. Flat and wave bottom plates were used.

All ties were numbered with metal tags and stenciled on tie ends for identification.

Details of the fastenings and methods of application are shown in Figs. 1, 2, 3, 4 and 5.

Upon completing the work of applying plates at Orrville, all ties were loaded and shipped to the test location and distributed on the right-of-way adjacent to track where

* This is an abstract of a report made to J. L. Gressitt, chief engineer, Pennsylvania Railroad Co. An earlier report on this same test in the form of a monograph by F. M. Graham, assistant engineer of standards, Pennsylvania Railroad, appeared in Bulletin 405, September–October 1938, page 65.

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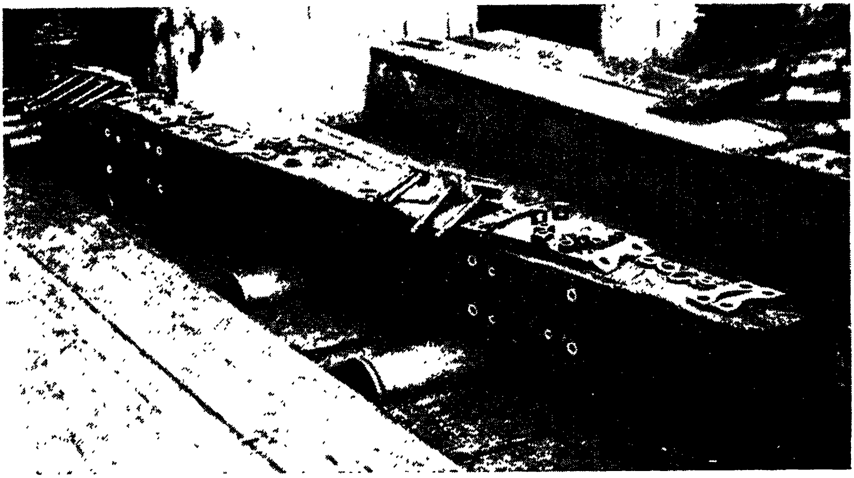


Fig. 2.—Tie with Parts Necessary for Through Bolt Assembly.

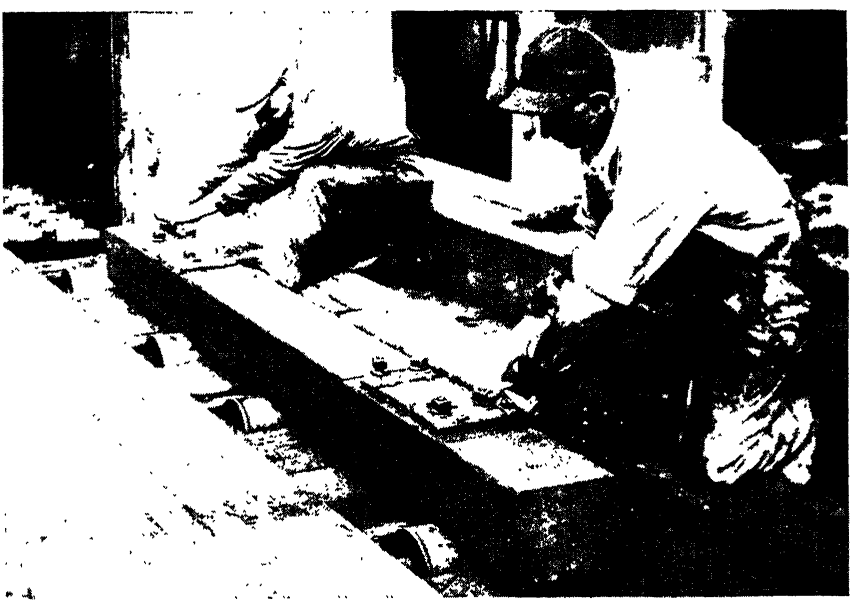


Fig. 3.—First Tightening of Through Bolts.

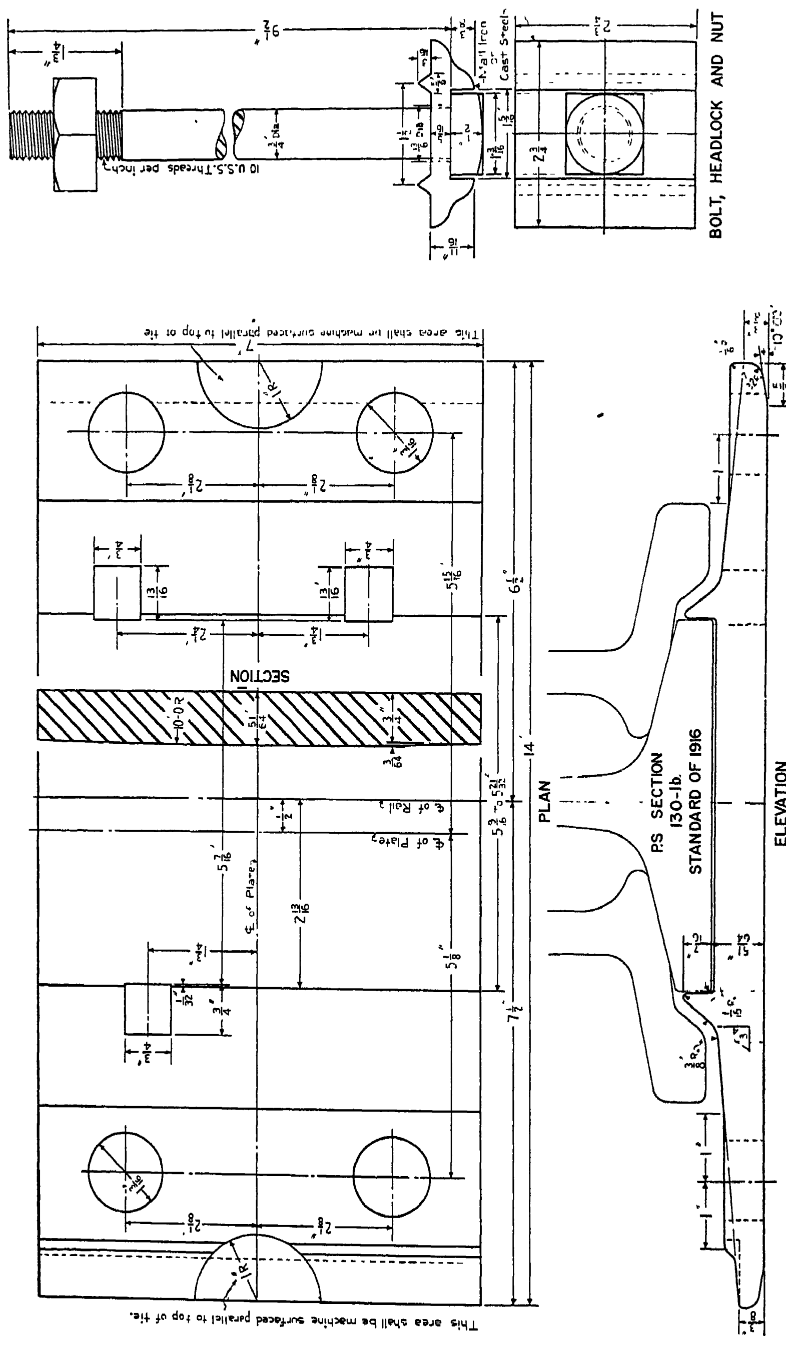


Fig. 1.—Details of Through Bolt Tie Plate Assembly.

Fig. 5.—Method of Applying Tie Plates with Cut Spikes at the Treating Plant.

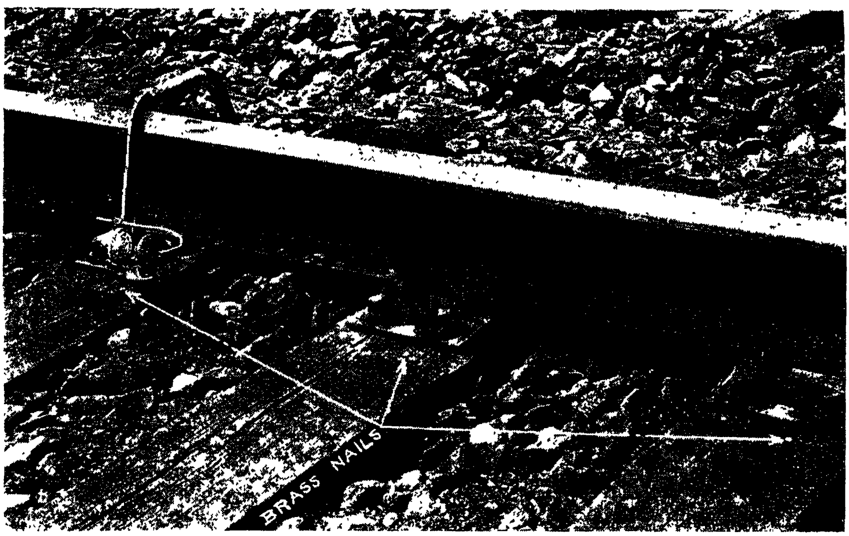


Fig. 6.—Instrument for Measuring Tie Plate Penetration; Showing also Special Machining of Tie Plates and Application of Brass Nails to Ties.

Fig. 4.—Applying Screw Spikes at the Treating Plant.

TABLE 1.—DATA SHOWING EXTENT OF TEST APPLIED IN 1929–1930

Test Symbol	*Wave or Flat Bottom*	*Method of Attaching Plate to Tie*	*No. of Ties in Test*	*No of Plates in Test*	*Date Applied*	*Degrees of Curve or Tangent*	*Elevation of Curves In.*
11T (A)	flat	4 through bolts	220	440	6–1930	tangent	
11C (A)	"	" " "	"	"	10–1929	4° 00′	3½
11T (B)	wave	4 through bolts	220	440	6–1930	tangent	
11C (B)	"	" " "	"	"	10–1929	4° 00′	3½
11T (C)	flat	4 screw spikes	220	440	10–1929	tangent	
11C (C)	"	" " "	"	"	6–1930	4° 30′	4½
11T (D)	wave	4 screw spikes	220	440	6–1930	tangent	
11C (D)	"	" " "	"	"	6–1930	4° 30′	4½
11T (E)	flat	2 cut spikes	220	440	6–1930	tangent	
11C (E)	"	" " "	"	"	6–1930	6° 00′	5
11C (F)	wave	2 cut spikes	22 0	440	6–1930	6° 00′	5

the ties were to be applied in out-of-face renewal. As shown on Table 1, certain portions of the test were applied in October 1929 and the remainder in June 1930.

Method

The test was conducted during a period of 18 years from 1929 to 1947. Observations and measurements of tie plate penetration gave information as to tightness of plates, holding power of spikes and bolts, and effectiveness of the three methods of tie plate fastening. Inspections were quite laborious, each requiring more than 10,000 measurements.

Results (Plate Penetration Measurements)

By referring to Table 1 it will be noted that the entire test was equally divided among the various kinds of fastenings and between tangents and curves ranging from 4 to 6 deg.

Plates with cut spikes were in track from 1930 to 1943, or for 13 years' service, and were removed primarily due to heavy plate penetration, splitting and shattering of ties, and generally unsatisfactory condition on the 6-deg. portion of a curve selected for this test.

Screw spikes were in track from 1929 and 1930 to 1943, or from 13 to 14 years' service, and were removed primarily due to penetration of the plates into the ties, excessive looseness of the screw spikes which, in many ties, could be lifted out by hand, and general deterioration of the ties such as splitting and shattering on a 4-deg. 30-min curve.

The through bolts were in track from 1929 and 1930 to 1947, or 17 to 18 years, and were removed primarily to replace 130-lb. PS rail with a heavier section. Plate penetration was not excessive, and from tie conditions it is estimated by the division forces that the ties could have remained in service for several additional years. The curvature for this test was 4-deg.

The tangent portion of the test was discontinued and fastenings removed at the same time that the curve was renewed in order to lay the heavier rail in a continuous stretch. The condition of ties and plate fastenings on the tangent would have permitted the test to be continued for several additional years, based on general condition of the ties.

All values of plate penetration referred to in this report are equated on the basis of 100 million gross tons over the track, the tonnage data being furnished monthly by the Middle Division. This is done to facilitate a direct comparison of plate penetration notwithstanding the fact that the ties and fastenings were applied and removed at different periods during the 18 years of test.

The total gross tons reported passing over the test track between the first and final measurements on both tangents and curves follow:

	Million Gross Tons
For cut spikes	610 to 614
For screw spikes	618 to 655
For through bolts	893 to 933

Before the tests were finally removed from track, about one year's additional tonnage had passed over track with each kind of fastening so that about one billion tons had passed over the through bolt test section during 18 years of service.

The average plate penetration on an equated tonnage basis is shown in detail in Table 2. These data are likewise shown in graphic form for direct comparison in Fig. 7.

A reasonable approximation of the actual average plate penetration may be obtained by multiplying any of the equated penetration values shown on Table 2 by 6.12 for cut spikes, 6.28 for screw spikes and 9.12 for through bolts, these constants being an average of reported tonnage for each kind of fastening expressed in millions.

From the detail data shown in Table 2, a series of tables numbered 3 to 7, incl., are presented, which show an analysis of information resolved into various classifications for simplification of comparison.

Table 3, a comparison on the basis of 100-percent penetration for the cut spike test, shows no outstanding difference between the cut and screw spikes, but penetration of plates with through bolts was only about one-third of that with the other two kinds of fastenings.

TABLE 2.—AVERAGE TIE PLATE PENETRATION PER 100 MILLION GROSS TONS FOR VARIOUS KINDS OF PLATES AND METHODS OF FASTENING

Location of measurements with respect to plate edges

Outside Rail		*Inside Rail*		*Both Rails*		*Both Rails*
Outside Plate Edge A	*Inside Plate Edge B*	*Inside Plate Edge C*	*Outside Plate Edge D*	*Outside Plate Edge A and D*	*Inside Plate Edge B and C*	*Outside and Inside Plate Edges A-B-C and D*
		(All values in inches)				
		Tangent				
		Flat-Bottom Plates Through Bolts				
.012	.010	.012	.012	.012	.011	.012
		Wave-Bottom Plates Through Bolts				
.017	.013	.013	.016	.017	.013	.015
		Flat-Bottom Plates Screw Spikes				
.048	.042	.040	.050	.049	.041	.045
		Wave-Bottom Plates Screw Spikes				
.043	.039	.035	.047	.045	.037	.041
		Flat-Bottom Plates Cut Spikes				
.043	.040	.038	.046	.045	.039	.042
		Wave-Bottom Plates Cut Spikes None Applied				
		Curve				
		4° 00′ Flat-Bottom Through Bolts				
.033	.004	.009	.012	.022	.007	.019
		4° 00′ Wave-Bottom Through Bolts				
.025	.005	.009	.018	.022	.007	.014
		4° 30′ Flat-Bottom Screw Spikes				
.056	.020	.034	.050	.053	.027	.040
		4° 30′ Wave-Bottom Screw Spikes				
.044	.028	.035	.052	.048	.032	.040
		6° 00′ Flat-Bottom Cut Spikes				
.042	.037	.031	.041	.042	.034	.037
		6° 00′ Wave-Bottom Cut Spikes				
.071	.052	.048	.073	.072	.058	.061
		Summary Tangent and Curve				
		Through Bolts				
.022	.008	.011	.015	.018	.010	.015
		Screw Spikes				
.048	.032	.036	.050	.049	.034	.042
		Cut Spikes				
.052	.043	.039	.053	.053	.044	.047

Penetration of the tie plate into the ties was determined at intervals by measuring the elevation of machined spots at each edge of the plates in relation to the top surface of oval head brass nails driven into the ties. The measurements were taken with a special instrument equipped with two Ames dials, which was designed and built at Altoona, Pa. The manner of using the instrument is illustrated in Fig. 6.

At each inspection, bolts and screw spikes were tightened with hand wrenches and cut spikes driven tight to bring tie plates tight against the tie surface prior to measuring the amount of plate penetration.

TABLES 3 TO 7, INCL., AVERAGE TIE PLATE PENETRATION SHOWING VARIOUS METHODS OF COMPARISONS AND CLASSIFICATIONS

All Values of Penetration in Inches, Equated to 100 Million Gross Tons Over Track

TABLE 3.—CLASSIFICATION BY PERCENT PENETRATION ON BASIS OF 100 PERCENT FOR CUT SPIKES

Kind of Fastening	Curves		Tangents		Curves and Tangents	
	In. Penetration	Cut Spike	In. Penetration	Cut Spike	In. Penetration	Cut Spike
Through bolts	.017	34	.014	32	.015	33
Screw spikes	.040	82	.043	102	.042	89
Cut spikes	.049	100	.042	100	.046	100

TABLE 4.—CLASSIFICATION BY FLAT AND WAVE BOTTOM PLATES

Kind of Fastening	Curves		Tangents		Curves and Tangents	
	Flat Bottom	Wave Bottom	Flat Bottom	Wave Bottom	Flat Bottom	Wave Bottom
Through bolts	.019	.014	.012	.015	.016	.015
Screw spikes	.040	.040	.045	.041	.043	.041
Cut spikes	.037	.061	.042	None Applied	.040	------------

TABLE 5.—CLASSIFIED BY PENETRATION ON LOW AND HIGH RAILS OF CURVES

Kind of Fastening	Outside Plate Edge		Gage Side Plate Edge		Outside and Gage Sides	
	Low Rail	High Rail	Low Rail	High Rail	Low Rail	High Rail
Through bolts	.029	.015	.005	.009	.017	.012
Screw spikes	.050	.051	.024	.035	.037	.043
Cut spikes	.057	.057	.040	.045	.049	.051

TABLE 6.—CLASSIFIED BY PLATE PENETRATION UNDER NORTH AND SOUTH RAILS OF TANGENTS

Kind of Fastening	Outside Plate Edge		Gage Side Plate Edge		Outside and Gage Sides	
	North Rail	South Rail	North Side	South Side	North Side	South Side
Through bolts	.014	.015	.013	.012	.014	.014
Screw spikes	.047	.046	.038	.041	.043	.044
Cut spikes	.046	.043	.038	.040	.042	.042

TABLE 7.—CLASSIFIED BY OUTSIDE AND INSIDE (GAGE) EDGES OF PLATES

Kind of Fastening	Curve		Tangent		Curve and Tangent	
	Outside Edge	Gage Side Edge	Outside Edge	Gage Side Edge	Outside Edge	Gage Side Edge
Through bolts	.022	.007	.014	.012	.018	.010
Screw spikes	.051	.029	.047	.039	.049	.034
Cut spikes	.057	.042	.045	.039	.053	.041

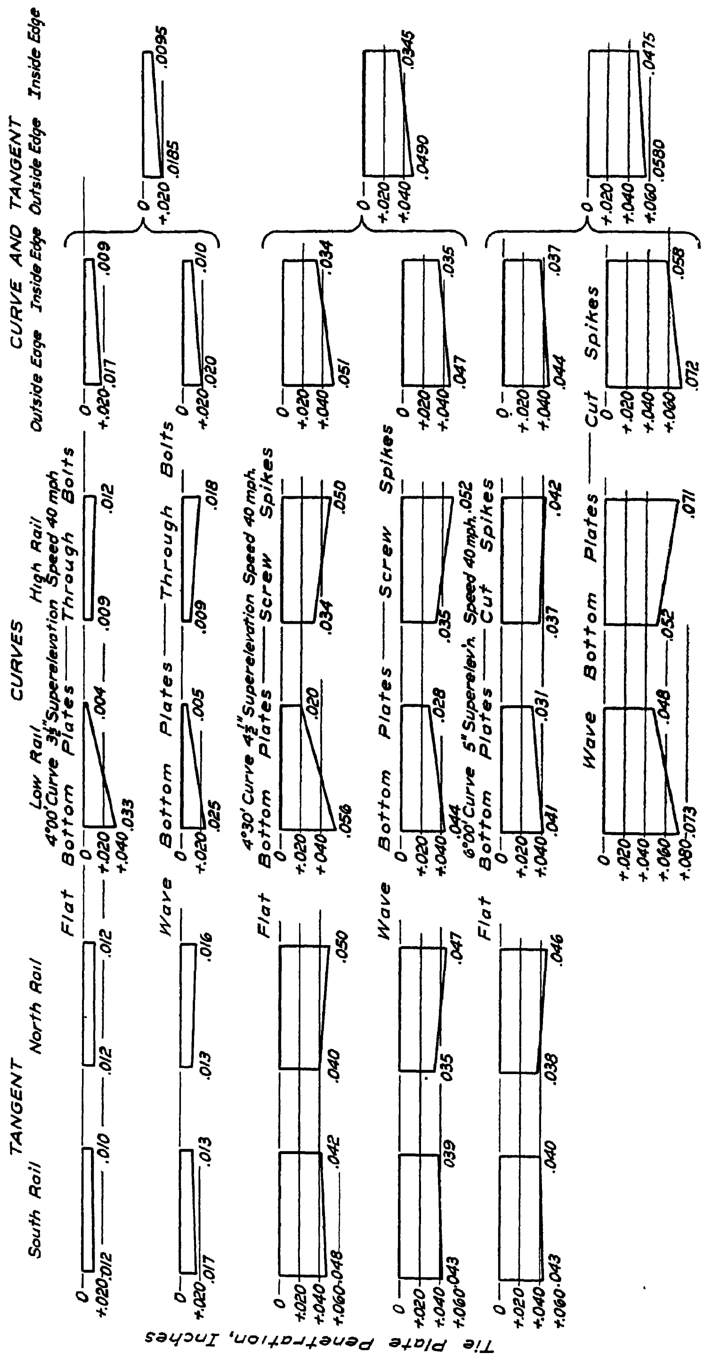


Fig. 7.—Graphic Record of Tie Plate Penetration.

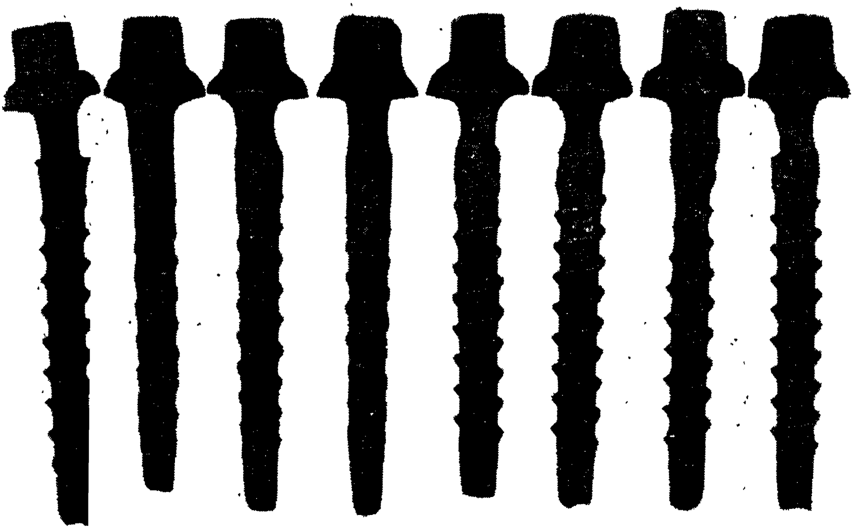


Fig. 8.—Showing Corrosion and Wear in Head Portion of Screw Spikes.

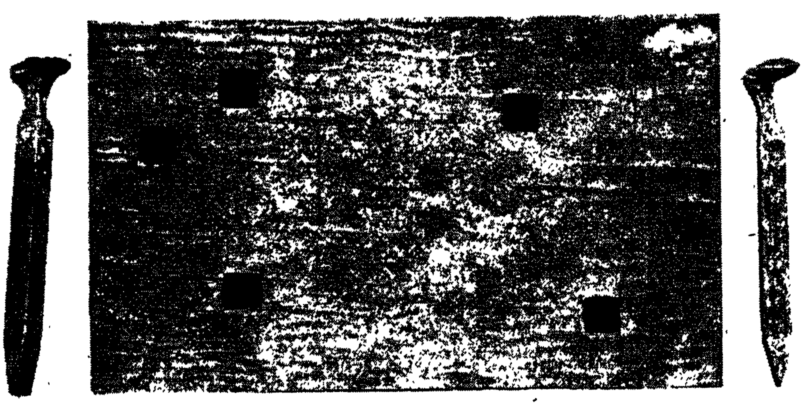


Fig. 9.—Showing Corrosion and Wear in Heads and Throats of Cut Spikes.

TABLES 8 AND 9—SHOWING AMOUNT OF TIGHTENING ON SCREW SPIKES AND THROUGH BOLTS BEFORE FINAL MEASUREMENTS

TABLE 8

Flat or Wave Bottom Plates	Tan. or Curve	No. of Bolts	No. of Spikes and Turns of Spikes to Tighten: 0	1/8 to 1/2	5/8 to 1	1 1/16 to 2	2 1/16 to 3	3 1/16 to 5	Over 5	Stripped, Broken, etc.
			Tightening record for screw spikes							
Flat	Tan.	1760	75	1411	216	18	0	0	0	40
Wave	Tan.	1760	130	1378	232	1	0	0	0	19
Flat	Curve	1760	71	1321	271	20	0	0	0	77
Wave	Curve	1760	96	1278	339	8	0	0	0	39
Total		7040	372	5388	1058	47	0	0	0	175
Percent of Total		100	5	77	15	1	0	0	0	2

Note: Screw spikes have 3 threads per inch, equivalent to turn or advance of 0.33 in. for 1 turn of the spike.

TABLE 9

Flat or Wave Bottom Plates	Tan. or Curve	No. of Bolts	No. Bolts and Turns of Nuts to Tighten: 0	1/8 to 1/2	5/8 to 1	1 1/16 to 2	2 1/16 to 3	3 1/16 to 5	Over 5	Stripped, Broken, etc.
			Tightening record for through bolts							
Flat	Tan.	1760	143	1219	202	111	32	12	1	40
Wave	Tan.	1760	103	1181	168	165	71	49	4	19
Flat	Curve	1584	214	817	97	135	98	119	27	77*
Wave	Curve	1551	199	726	168	150	120	128	27	33**
Total		6655	659	3943	635	561	321	308	59	169
Percent of Total		100	10	59	10	8	5	4	1	3

*176 bolts and **209 bolts damaged May 1941 by derailment not included.
Note: Through bolts have 10 threads per inch, equivalent to turn or advance of 0.10 in. for 1 turn of the nut.

Table 4, a comparison of penetration by flat and wave bottom plates, shows no appreciable difference between the two kinds of plates used with screw spikes and through bolts. For cut spikes on curve track, wave bottom plates penetrated almost twice as far as flat bottom plates. No wave bottom plates were applied on tangent; therefore, comparison with penetration of flat bottom plates cannot be made.

Tables 5, 6 and 7 show comparisons of plate penetration classified with respect to plate edges for each rail on tangents and curves. In Tables 5 and 6 it will be noted that there was no outstanding difference between the high and low rails of curves and north and south rails of tangents.

Table 7 shows that in all cases, penetration was greater at the outer plate edge for both tangents and curves. The average difference for the three kinds of fastenings on tangents was 0.005 in. and on curves 0.017 in.

Table 8 shows a record of the amount of tightening required for the screw spikes immediately before the final inspection, and similar information is shown for the through bolts in Table 9 before final measurement.

It should be observed in notes included with each table that while the screw spikes were advanced 0.33 in. for each full turn of the spike, the through bolts were advanced only 0.10 in. for each full turn of the nut due to the difference in threads per inch. From this comparison a measure of the relative looseness of the two kinds of fastenings, can be obtained. In this connection it should be remembered that ties with through bolts had 4 years' additional life and were in much better condition when removed than ties with screw spikes.

Standard lock washers were used under the nuts of the through bolts. No washers were used in this test under the screw spikes.

Visual Inspection Before and After Removal

For the cut and screw spike portions of the test eight complete sets of penetration measurements were taken over a service period of 12 to 13 years. These two types of plate fastenings were removed in 1943. Both cut and screw spikes were heavily corroded in the spike head portion and severely "throat cut." On many of the screw spikes the socket wrench could not be used due to corrosion of spike head and there was excessive breakage of the cut spikes during removal due to heavy corrosion and "throat cut" condition.

Figs. 8 and 9 show representative conditions of the two kinds of spikes when this portion of the test was concluded.

Removal of the cut and screw spike fastenings in 1943 also included most of the ties on curves due to heavy plate penetration, end splitting, and otherwise unsatisfactory tie conditions.

Although tie conditions on the tangent portions of the test with screw and cut spikes were better than on curves as regards splitting and general deterioration, the penetration of plates was quite extensive with these two kinds of fastenings even on the tangents (Table 7) and it was decided to discontinue the test on both tangents and curves at the same time.

Before removal in 1943, final penetration measurements and photographs were taken to show general conditions representing 12 to 13 years' service. For comparison, views of the through bolt portion of the test were also taken, although removal of the ties with this method of fastening was not being considered at this period due to good condition of ties and bolts.

The photographs taken at this time showing general conditions of all plate fastenings used in the test are reproduced in Figs. 10, 11 and 12.

Except for damage by derailment in May 1941 to some of the through bolts on curve track, this method of fastening continued in service 4.5 additional years, or until October 1947, making a total of 18 years' service before removal. It was estimated that ties with through bolts would have given satisfactory service for several additional years; however, it was becoming increasingly difficult to get good fit 130-lb. rail for this heavy tonnage track and the division requested permission to lay heavier rail. With the heavier and wider base rail this method of fastening required an out-of-face renewal of all plates, bolts, and ties. This renewal was extended through the tangent portion adjacent to the curve to provide for a continuous stretch of the heavier section rail.

Before removal of the bolted fastenings, final plate penetration measurements and photographs were taken to show conditions at the conclusion of the test. Two of the photographs are shown in Figs. 13 and 14.

It is evident from penetration measurements (Table 3) and Figs. 13 and 14 that with through bolts it was possible to maintain plates tight to the ties, resulting in relatively small penetration and deterioration of ties on both the 4-deg. curve and the tangent.

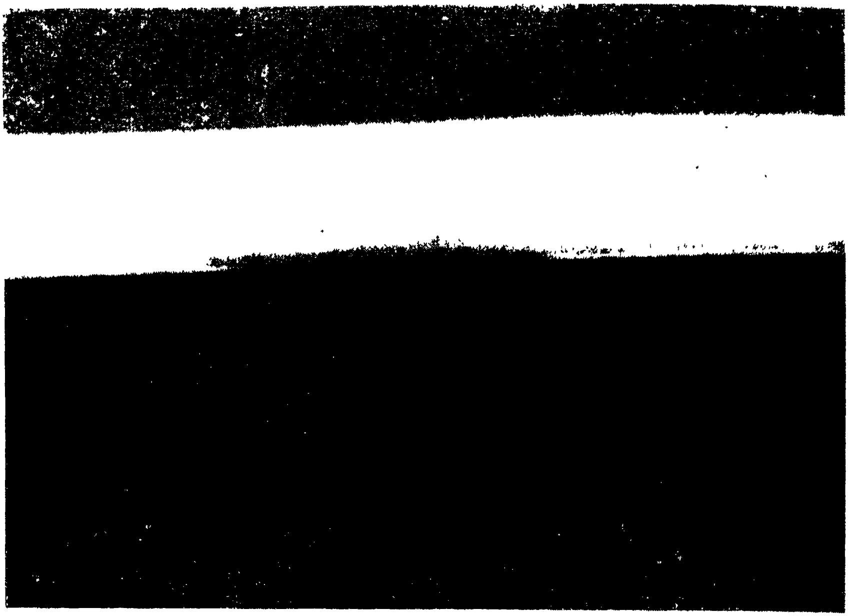


Fig. 10.—Through Bolts, Showing Condition on Low Side of 4-deg. Curve in 1943, When Cut and Screw Spike Installations Were Removed.

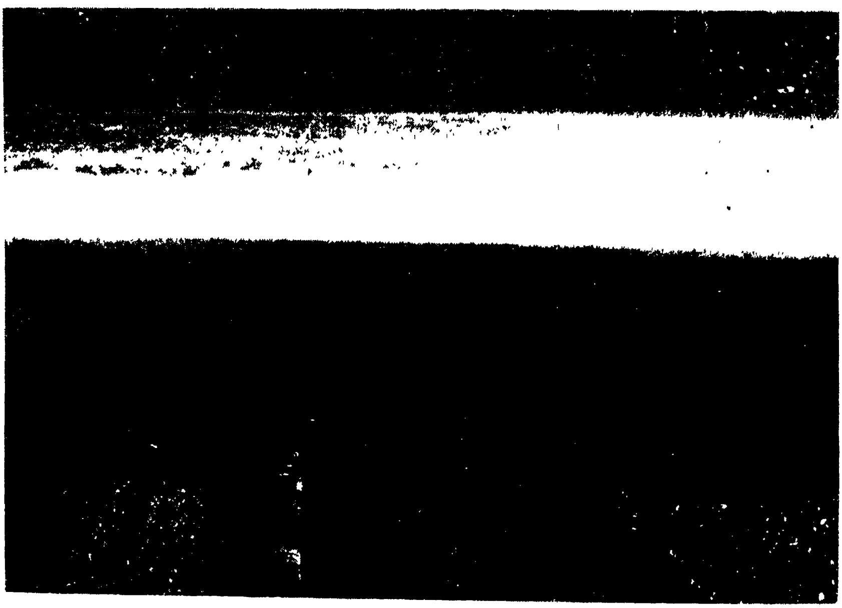


Fig. 11.—Screw Spikes, Showing Condition on Low Side of 4-deg. 30-min. Curve in 1943, Immediately Before Removal.

Fig. 14.—Through Bolts, Condition on 4-deg. Curve, High Rail, Immediately Before Removal in 1947, After 18 Years' Service.

Fig. 15.—Through Bolts, Tie Condition After Removal From High Side of a 4-deg. Curve in 1947, After 18 Years' Service.

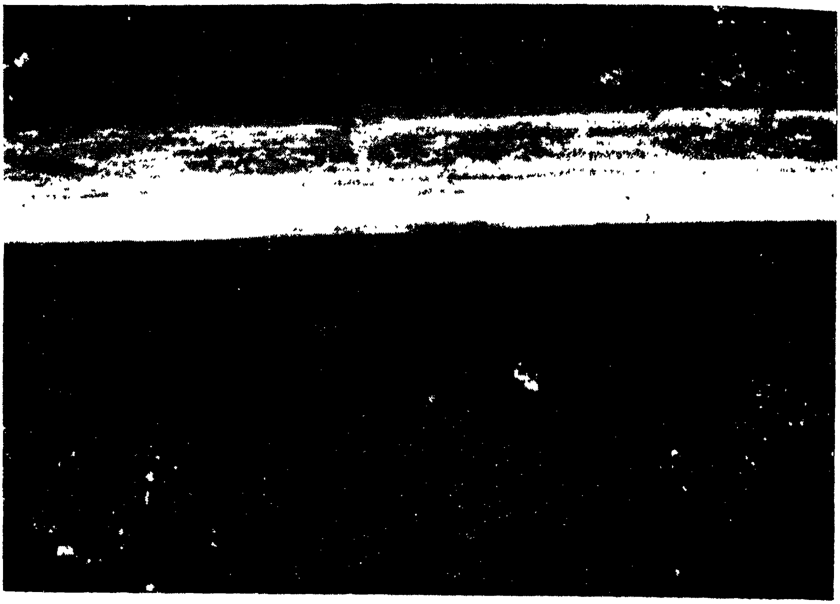


Fig. 12.—Cut Spikes, Showing Condition on Low Side of 6-deg. Curve in 1943, Immediately Before Removal.

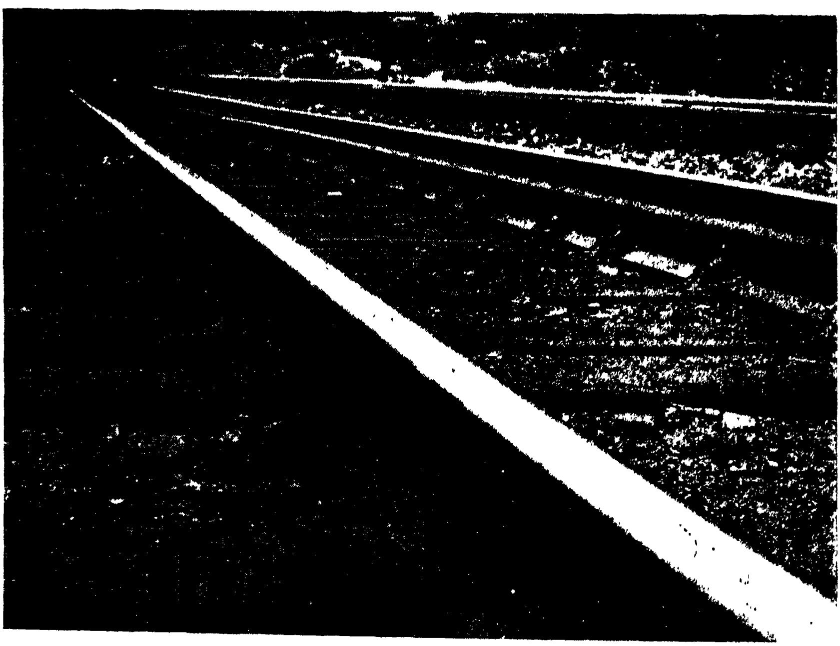


Fig. 13.—Through Bolts, Condition on Tangent Track, South Rail, Immediately Before Removal in 1947 After 18 Years' Service

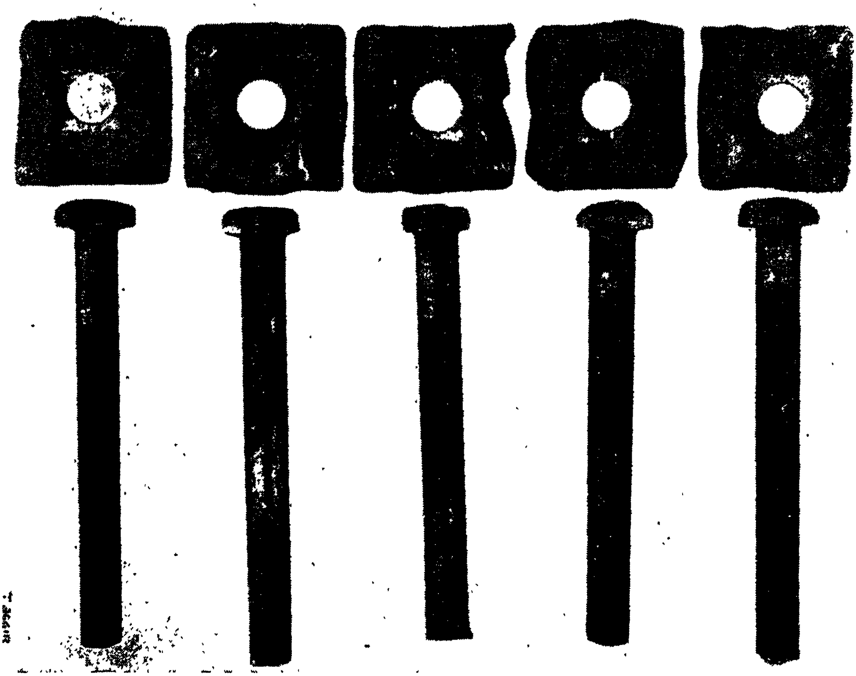


Fig. 17.—Through Bolts, Condition of Bolts and Headlock Washers Removed in 1947, After 18 Years' Service.

The test of the two special methods of fastenings compared with ordinary plate fastenings under extremely heavy tonnage during a long period of service has developed information which is the basis of the discussion to follow.

Screw Spikes

During the early period of test the screw spikes remained tight and plate penetration was small and materially less than for cut spikes.

With increasing service there was a similar increase in looseness of screw spikes and plates due to thread deterioration in the wood of the tie until at the conclusion of the test there was very little difference in plate penetration and tie conditions between cut and screw spikes, and many of the screw spikes could be lifted out of the tie by hand, particularly on the 4-deg. 30-min. curve.

A characteristic example of thread deterioration is illustrated in Fig. 19, showing a tie that was removed after about 6 years' service and sectioned by sawing to show the thread condition. We believe that under traffic, forces applied to the rail, particularly lateral forces, cause small movements of the spike sufficient to enlarge the hole in the tie. This permits entrance of water and foreign substances sufficient to cause the gradual but progressive destruction of threads in the wood of the tie and ultimate failure of the screw spike as an efficient plate fastening or holding device.

It will be noted in Fig. 19 that evidence of thread distintegration extends for six threads or about two-thirds the length of spike. This condition has occurred at about the half-way period in the test, and during the remaining half of the test there was

Fig. 16.—Through Bolts, Wear on Bottom Side of Tie From Tangent Portion of Test, Removed in 1947 After 17 Years' Service.

Immediately after the ties with bolted plates were removed from track in October 1947 the test material was examined to determine conditions after 18 years' service and about one billion tons of traffic. At the same time photographs were taken to illustrate the conditions observed in the removed ties and fastenings, and these conditions are illustrated in Figs. 15 to 18, incl.

The bolts were ¾ in. diameter driven into ¾-in. prebored holes. In the removal of bolts for examination at the conclusion of the test it was necessary to drive the bolts out of the ties. The corrosion in the shank of the bolts was very slight although the bolt head and malleable washer on the underside of the tie showed considerable corrosion. Prebored holes in the ties showed excellent condition of wood, with no evidence of wear, looseness or deterioration (Fig. 18).

Discussion

In the original authority under the heading of "Purpose of Test" we find the following:

> Present track construction results in a very considerable abrasion and cutting of ties by tie plates, causing reduced life of ties, and increased labor cost in maintaining correct track gage, line and surface.
>
> It is believed that if tie plates can be held in contact with the tie at all times without motion between them, tie abrasion and cutting will be stopped or much reduced. This test is intended to find means to stop such motion.

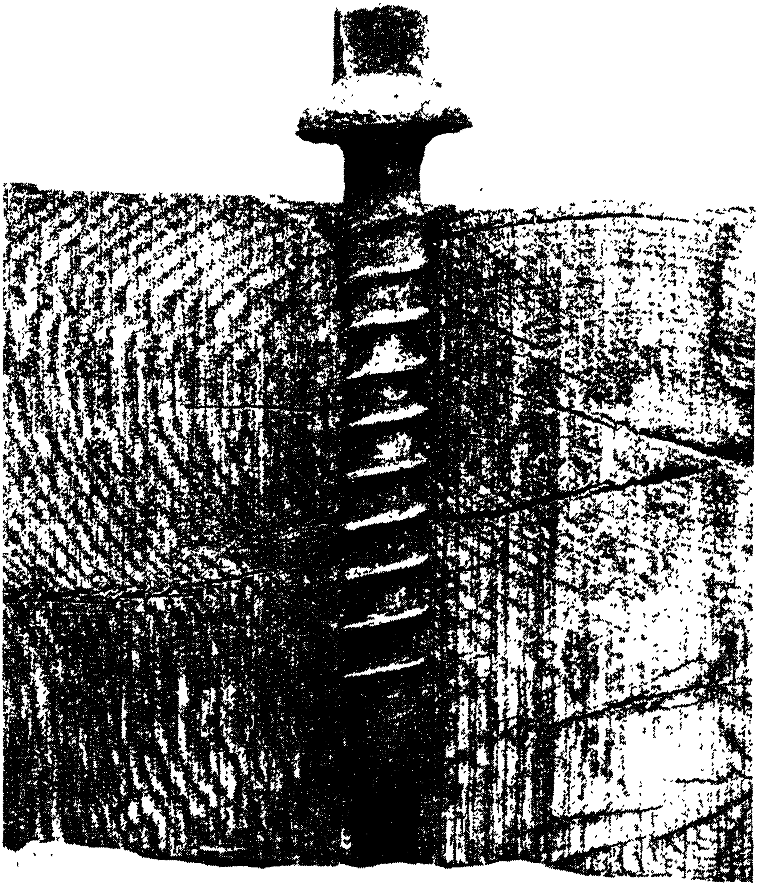


Fig. 19.—Screw Spikes—Section Showing Progress of Thread Destruction in Tie After About 6 Years' Service.

Through Bolts

Throughout 18 years of service the through bolt method of fastening was extremely effective in retarding penetration of plates. It will be noted in the comparison on Table 3 that plate penetration with through bolts was about one-third the penetration with cut and screw spikes and the increased tie life was about four years. Except for urgent need to re-lay the track with heavier rail, it is estimated the tie life with through bolts would have been extended several years.

Division forces report that good gage, line, and surface were maintained with less labor on track equipped with through bolts than on track with cut and screw spikes. From the standpoint of plate penetration, end splitting, and shattering of ties and general deterioration of the wood and plate fastenings, it was readily noticeable that ties with through bolts were in far better condition than ties removed after four years' less service with cut and screw spikes.

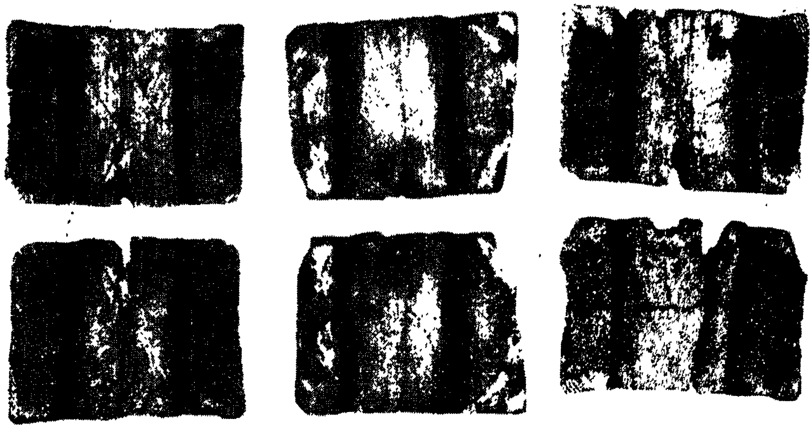


Fig. 18.—Through Bolts, Condition of Prebored Holes in Ties Removed in 1947, After 18 Years' Service.

insufficient holding power of the spike to maintain the spikes or plates tight, thus permitting movement and accelerated penetration of plates about equal to that of the tie plates installed with cut spikes.

We believe that Fig. 19 depicts a representative condition that would ultimately result in the failure of screw spikes when used either for rail or plate fastening.

Information developed in another test, shows that where coil washers were used under the screw spike heads there is less plate and spike looseness. This condition was evident in track carrying same traffic and annual tonnage. A similar improvement might have resulted from use of spring washers with screw spikes in the test, covered by this report. However, the same character of failure through destruction of threads in the tie would ultimately develop, and destroy the effectiveness of screw spikes as a plate fastening.

Another difficulty experienced with screw spikes after about six years' service was the increase in corrosion and rounding of spike head corners which seriously interfered with tightening of spikes, many of which could not be turned with socket wrenches. The excessive reduction in diameter of the spikes under the head due to wear and corrosion aggravated plate looseness and holding power of the spikes.

Before removal of the cut and screw spikes in 1943 a final inspection was made. This inspection included the through bolted ties which subsequently remained in service for an additional four years. An outstanding condition noted at this inspection, in addition to the greater amount of plate penetration occuring with the two kinds of spikes, was the shattering and spliting of the wood in ties with both cut and screw spikes due, in our opinion, to inability to maintain plates, spikes, and screws in a satisfactory and tight condition. A similar inspection of the ties with through bolts at this time and again four years later in 1947, before and after removal, indicated no serious splitting or shattered condition of the wood such as was earlier observed with the cut and screw spikes. Also, plate penetration with bolts was relatively light.

The most objectionable tie conditions were found in all cases on curves.

3. Each composite through bolt assembly, including the tie plate, comprised 25 separate parts, or 50 parts per tie, exclusive of the rail spikes. A manifold assembly of this magnitude is considered highly undesirable.

General

The eccentricity provided in the 130-lb. PS heavy-duty tie plates used in this test was ½ in.

A study of the data with respect to plate eccentricity shows that on tangents there was no outstanding difference between the penetration at the outer and inner edges of plates on either rail for any of the three methods of fastenings. The average difference between the penetration at the inner and outer edges of the plates under the north (inside) rail was 0.007 in., and south (outside) rail was 0.004 in., the average difference for both rails being 0.005 in.

Plate penetration on curves indicates that some increase in eccentricity might be beneficial. An analysis of the through bolt penetration where it was possible to maintain the plates tight throughout the test shows greater penetration on the low rail, as would be expected in this combined freight and passenger track. It will be noted that the maximum penetration occurs at the outer edge of the plate on both rails, the average difference between the two edges being 0.025 in.

Similar trends in penetration are shown for the cut and screw spikes on curves, but plate looseness experienced during the latter period of the test may have influenced the amount of penetration at both plate edges; therefore, the through bolt method only is considered in this analysis.

Conclusions and Recommendations

1. The method of fastening tie plates to ties with four screw spikes per plate (without spring washers) shows for the total period of test little or no improvement over results obtained with cut spikes, using two spikes per plate. Its further use is not recommended.

Failure of screw spikes was due to:

(a) Destruction of threads in ties, permitting removal of many spikes by hand.

(b) Heavy corrosion and "throat cutting" of spikes.

(c) Rounding of spike head corners, preventing proper tightening.

Ties with both screw and cut spikes showed serious mechanical damage by plate penetration, splitting, and shattering of the wood.

2. The method of fastening the tie plate to the tie by the use of four through bolts per plate gave greatly improved results over those obtained with cut spikes. The improved results were evidenced by:

(a) Reduced penetration of the plate into the tie, about one-third of that with cut spikes and screw spikes.

(b) Reduced end splitting and the absence of shattering of ties, with increased life of ties amounting to four years, or 29 percent actual, and probably seven years, or 50 percent increase in life, if it had not been necessary to remove the ties and plates for laying heavier rail.

The outstanding advantages obtained with through bolt method of fastening can be attributed to the following:

1. More rigid assembly with four through bolts, which hold the plates tight to the tie and prevent movement under traffic.

2. Initial seating of tie plates on new ties with an applied pressure of 30,000 lb. before the bolts were given final tightening. This was not done with cut and screw spikes.

3. Considerable resistance to end splitting of ties was developed with the through bolt method of fastening, due to the use of the four bolts, two on the outer and two on the inner plate edges, each pair of bolts being connected by metal plate washers placed over an insulation washer.

Examination of the through bolt ties after removal shows that a far greater amount of deterioration has occurred on the underside of the tie due to penetration and abrasion by the stone ballast than occurred on the top surface. Rough measurements indicate as much as a two-inch loss of tie thickness due to this condition, as shown in Fig. 16.

Although the through bolt method of fastening gave outstanding service in maintaining plates tight to the ties over a long service in heavy tonnage track, thus fulfilling the purpose of the test, we do not consider the through bolt method of fastening either economical or practical from the standpoint of its general use on the railroad.

1. A major disadvantage in the use of through bolts was the relatively high first cost of the tie plate assembly, including labor and material. A comparison of the cost per tie, exclusive of the new tie cost of $2.42, which included adzing and boring common to all methods of fastenings, was as follows:

Through bolts	$5.94
Screw spikes	$3.61
Cut spikes	$2.94

It is recognized the above costs were probably excessively high due to the special nature of the work; however, a comparison of costs estimated on the basis of commercial use did not reduce them to the point where the method would be considered economical.

2. Renewal of bolts by reason of damage or other emergency causes, or in replacing tie plates for heavier rail, necessitated removal of ties from track. This would be impracticable and uneconomical from the standpoint of general use.

In removing the through bolts in October 1947, at the time of laying heavier rail the procedure used was as follows:

(a) Top portion of four through bolts on top of tie plates was burned off with an acetylene torch.

(b) 130-lb. plates were removed, leaving stub ends of bolts projecting from the tie surface.

(c) Second burning of stub ends of bolts, bringing burned ends about flush with the tie.

(d) Wood shims ½ in. thick to insulate tie plates from bolts and protect signaling circuit were temporarily applied under new 152-lb. plates at the time the heavier rail was laid.

Later, all ties were renewed out of face.

A Study of the Behavior of Floorbeam Hangers

Static and Dynamic Stress Measurements on the Illinois Central Railroad Bridge at Galena, Ill.

By L. T. Wyly,[1] M. B. Scott,[2] L. B. McCammon,[3] and C. W. Lindner[3]
Purdue University Engineering Experiment Station

Digest

This report embraces a description and analysis of static and dynamic tests made on the floorbeam hangers of the 127-ft. through truss span of the Illinois Central Railroad, near Galena, Ill. It is the first report issued on the floorbeam hanger research project being conducted at the Engineering Experiment Station at Purdue University with the assistance of the research office, Engineering Division, AAR.

Using SR-4 resistance gages, stresses were measured at 11 sections of each hanger $U_1 - L_1$, a total of 228 gages being used for the static tests and a total of 64 gages being used on the dynamic tests.

The purpose of the tests was to investigate the effects of form of hanger section, and of floorbeam and stringer deflection upon stress distribution in the hanger. The hanger section consists of two channels connected together only by occasional tie plates.

Graphs and diagrams showing the measured and calculated stresses are given. A theoretical treatment is also included.

The principal conclusions are:

1. A substantial diaphragm between the two channels of the hanger at the floorbeam connection was not sufficient to transfer half the floorbeam reaction to the outside channel. At the top of the floorbeam bracket, section H-11, the inside channel carried about 50 percent more load than the outside channel, see Fig. 4.
2. Tie plates alone do not form a satisfactory system of bracing for a floorbeam hanger.
3. The use of such a tie-plated section results in severe local bending in the channels at the tie plates due to the racking set up in transferring load from the inside to the outside channel, see Fig. 9.
4. The bending stresses resulting from rigid frame action and racking action were more than 100 percent of the average axial stresses in the hanger tested.
5. All the measured stresses can be accounted for in a rational manner, but not by the usual methods of analysis.
6. For this type of member, a plane section before bending does not remain a plane section after bending, since the components are not tied together and each channel tends to act individually.
7. Stress distribution in the individual components is planar except where modified by local stress concentrations, such as occur at rivet holes.
8. For this type of member, gages on the four corners only will not give a true picture of either total load or of stress distribution.
9. The dynamic stresses showed the same type of stress distribution as the static stresses. (See Fig. 12.)

[1] Research professor of structural engineering and head of department.
[2] Assistant professor of structural engineering.
[3] Instructors in civil engineering, respectively.

3. The method of fastening used in this test with four through bolts, head locks on the bottom of the tie, insulation, and washer plates at the top of the tie, is not practical for general use. Its further use is not recommended.

(a) It involved excessive initial costs.

(b) It involved multiplicity of parts.

(c) It necessitated removing the ties from track under any circumstances requiring tie plate renewal. This proved awkward and costly when the ties were finally removed.

4. Some method of through bolting should be given consideration, if one can be found materially less cumbersome and inconvenient than the one tested.

5. Continued study and testing, looking toward a practical and economical method of fastening the tie plate to the tie so as to eliminate relative movement, is recommended.

or four angles connected at intervals by tie plates only. The bridge selected provides all of the above features.

The Galena bridge was built in 1941 and was designed for E–72 loading. (See Fig. 1, a, b.) The hangers are composed of two channels 12 in., 30 lb., connected by tie plates spaced 4 ft. 6 in. center to center. The bridge is owned by the Illinois Central Railroad but as it is in joint track territory, it also carries trains of the Chicago, Burlington, & Quincy Railroad, and the Chicago Great Western Railway.

The general procedure in making the static tests was to take zero readings upon the unloaded bridge, followed by live load readings with a test train on the bridge and finally another set of zero readings. All readings were taken at night to minimize temperature effects. Class 2800 engines (2–10–2) of the Illinois Central were used for the test train, the third driver being located directly over the center of the floorbeam at L_1. Three such test runs were made.

For making the dynamic tests on the hanger, four of the sections used in the static tests were selected. The sections H–2, H–6, H–7, and H–8 (on both trusses) are located as shown on Fig. 4. In most cases, the gages used in making the static tests were re-used in the dynamic tests at these sections. Several damaged gages had to be replaced.

The dynamic tests were made during the day under regular train service. This was possible since the individual dynamic runs are of such short duration that temperature effects are eliminated. The railroad, the engine number, the speed, and other pertinent data were recorded for each run and correlated with the oscillograph records taken at the sections during the passage of the train.

Fig. 1, a.—The Galena Bridge of the Illinois Central Railroad.

10. All impact loads (total load in the hanger) for the loadings studied were found to be well within the present AREA specification allowances. (See Fig. 13.) It is important to note, however, that the actual measured dynamic unit stress at a particular point is over 2.5 times as great as the average axial unit stress in the hanger. For example in Fig. 12 at section H-6 for the speed of 47.1 mph., the largest measured dynamic stress is shown as 16.89 ksi. This stress is 2.6 times the average axial static unit stress of 6.5 ksi in the hanger. This ratio is as high as 2.75 at section H-6 at a speed of 43.4 mph., in another run.

11. A rational design of the floorbeam hanger frame using this type of hanger section does not appear to be practicable.

12. Any realistic estimate of stresses in a floorbeam hanger must include the effects of the interaction in the rigid frame composed of the hangers, floorbeam and stringers, and any transverse bracing, due to:

(a) Floorbeam and stringer deflection.
(b) Transverse displacement of the hanger at the top of the floorbeam bracket due to rotation at the end of the floorbeam.
(c) Any restraints imposed by the bracing or truss framing.

13. This type of floorbeam hanger may not be expected to have good fatigue strength due to the excessive local bending which occurs.

Foreword

The investigation covered in this report, which embraces the first of the structures to be tested, is part of the floorbeam hanger research project being conducted at the Purdue University Engineering Experiment Station, under the direction of Professor L. T. Wyly. Administration is by Dr. A. A. Potter, director of the Engineering Experiment Station, and dean of engineering, and by Professor R. B. Wiley, head of the School of Civil Engineering and Engineering Mechanics, where the work is being done. The project is sponsored financially by the Association of American Railroads. It was initiated upon the recommendation of AREA Committee 15—Iron and Steel Structures, and is supervised by the subcommittee on stresses in bridge frames—floorbeam hangers. The AAR, Engineering Division research office, under the general direction of G. M. Magee, research engineer, assists and advises regarding the work, and conducts the dynamic tests.

All gages were placed and static readings taken by the Purdue staff. The dynamic tests were made by the AAR, Engineering Division research staff under the general direction of E. J. Ruble, structural engineer. All data were analyzed and the report written by the Purdue forces. The Illinois Central Railroad built the scaffolds and provided the test train.

It was generally agreed that the first problems to be studied in this project were:

1. The effect of form of hanger section upon the stress distribution in the member under static loads.
2. The general distribution of stresses in the hanger resulting from floorbeam deflection.
3. The effect of dynamic loads in the above studies.

The features desired in the first bridge to be tested were a single track structure with open timber deck, of modern design under present specifications, located in high speed territory, carrying heavy live loads of frequent occurrence. It was also desired to use Pratt or Warren riveted trusses, having hanger sections composed of two channels

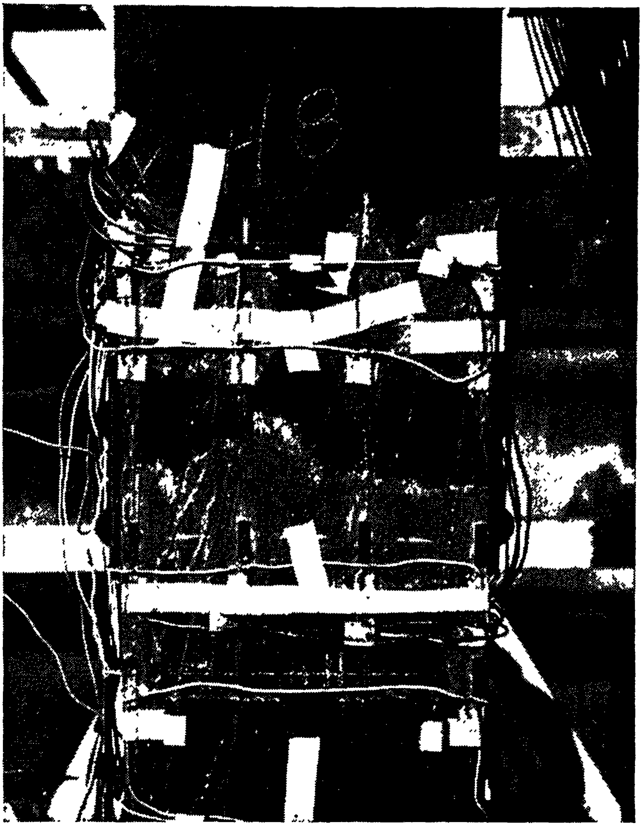


Fig. 1, c.—Method of Applying Strain Gages.

gages to the switch boxes was No. 16 solid copper with waterproof plastic (Gencaseal) insulation. The switch-boxes, from the Purdue structural laboratory, were equipped with 10-point silver selector switches. They were made under the supervision of L. T. Wyly, and included special features recommended by the AAR research office.

The closest reading on this instrument is one micro-inch (one-millionth inch) corresponding to a stress change of 30 psi. In this report, the modulus of elasticity of the steel has been assumed at 30,000,000 psi. Under laboratory conditions, unless elaborate controls are used, the errors in stress change given with this equipment may be several percent, and under field conditions the error may be greater. It is believed that the maximum error in any individual reading reported here does not exceed five percent.

Dynamic Strain Gage Instruments

The strains in the floorbeam hangers under the moving trains were measured by the dynamic strain gage equipment owned by the AAR and operated by its research staff. The equipment consisted essentially of the following:

Fig. 1, b.—A View Through the Tested Span.

A total of 131 runs was recorded under various classes of locomotives. However, this report covers only the static and dynamic tests of the Illinois Central Class 2800 locomotives. For the dynamic tests, several runs were made at 4 to 10 mph. and the principal dynamic runs were made from 40 to 57 mph.

Instruments

Both static and dynamic readings were made with SR–4 resistance gages.

The static tests were made using a type K portable strain indicator (d.c. balancing bridge using the null method) manufactured by the Baldwin Locomotive Works. Gages were placed at eight sections just above or below the tie plates at sections H–2 to H–8, incl., and H–11. In addition, gages were placed on three sections taken through the rivet holes at the bottom of gussets and at the first tie plates above the floorbeam at H–1, H–9, H–10. (See Figs. 2, 3, and 4.) The gages all had 1-in. nominal gage length except those adjacent to the rivets which had a nominal gage length of ¼ in. These latter gages were placed about ¼ in. from the edge of the rivet hole, the edges of the rivet heads having been ground down slightly to permit this. The total number of 1-in. gages used was 160 and the number of ¼ in. gages used was 68. The wire leading from the

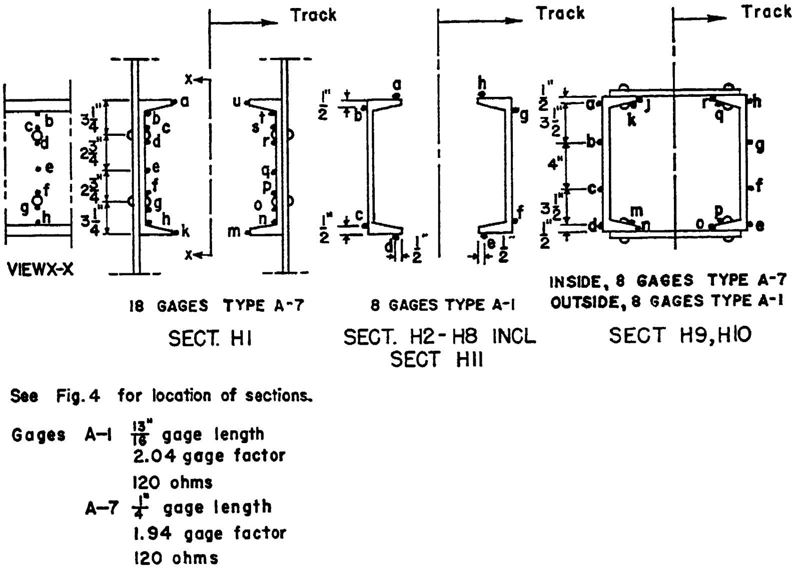


Fig. 3.—Location of Gages at Sections A–A on North Truss.

The power unit regulates the output current over reasonable changes in the input voltage and load changes.

The 110 volt 60-cycle input circuit for these tests was provided by a 2500-watt Homelight 2-cycle gasoline engine-generator unit.

Amplifier Unit.—The output from the wire resistance indicating gages is insufficient to swing the 7-ohm magnetic galvanometers in the oscillograph so it is necessary to amplify this output a considerable amount. The amplifier unit has 12 separate amplifiers in one cabinet with a panel for their control and calibration.

The amplifiers are the carrier wave type and the high frequency current of 5000 cycles per second is applied to each bridge circuit. The bridge circuits are then balanced for capacity and resistance by the amplifiers' control panel. The inductance is negligible. The amplifier alternating current output from the bridge circuit is rectified by a discriminator circuit that makes the output phase sensitive so that a tension in the steel will deflect the galvanometer in one direction and a compression in the opposite direction.

A current output of 50 milli-amperes is available from each amplifier so that a stress in the steel as low as 1000 psi. will deflect the light from the galvanometer mirror about 1 in. This means that the strain gage equipment is capable of magnifying the actual strains in the steel by about 30,000 times.

The amplifiers have a flat frequency response up to 1500 cycles per second which is above the frequency response of the galvanometers in the oscillograph and well above any frequency encountered in railroad structures.

Oscillograph.—The oscillograph is a light-proof case with a row of 12 magnetic galvanometers at one end, a light source and focusing prisms in the center, and a moving film, 10-in. in width at the other end.

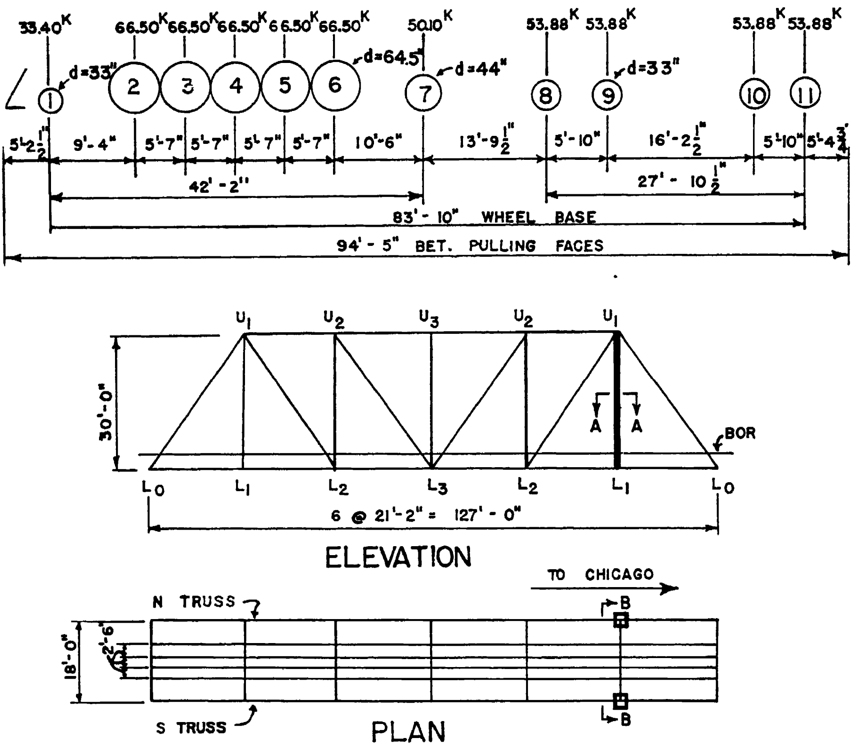


Fig. 2.—Diagrams of the Test Span and Test Locomotives.

Wire Resistance Gages.—The wire resistance or SR-4 gages used in these tests for both the static and dynamic readings consist essentially of a grid of fine resistance wire about 0.001 in. diameter cemented to a piece of special paper. The gage is fastened to the steel by lacquer cement which is absorbed by the special paper so that the wire and paper are thoroughly bonded to the surface of the steel. The gage is then coated with Petrosene wax to keep out all moisture.

The gage cemented to the steel in which the strain is to be measured, called the indicating gage is placed in one arm of an electrical bridge circuit while a similar gage or balancing gage is placed in the other arm of the circuit. A strain in the steel produces the same strain in the wires of the indicating gage resulting in a resistance change in this gage. In operation, a carrier current of 2 volts, 5000 cycles per second is applied to the bridge circuit. A strain in the steel of 0.0005 in. over 1-in. gage length, which is equivalent to a stress of 15,000 psi. produces a change of about 0.001 volts in the circuit.

Power Unit.—The 2-volt high-frequency carrier current of 5000 cycles per second for the bridge circu't and a regulated direct current plate supply for the amplifiers are supplied by an electronic power unit operating directly from 110-volt 60-cycle current

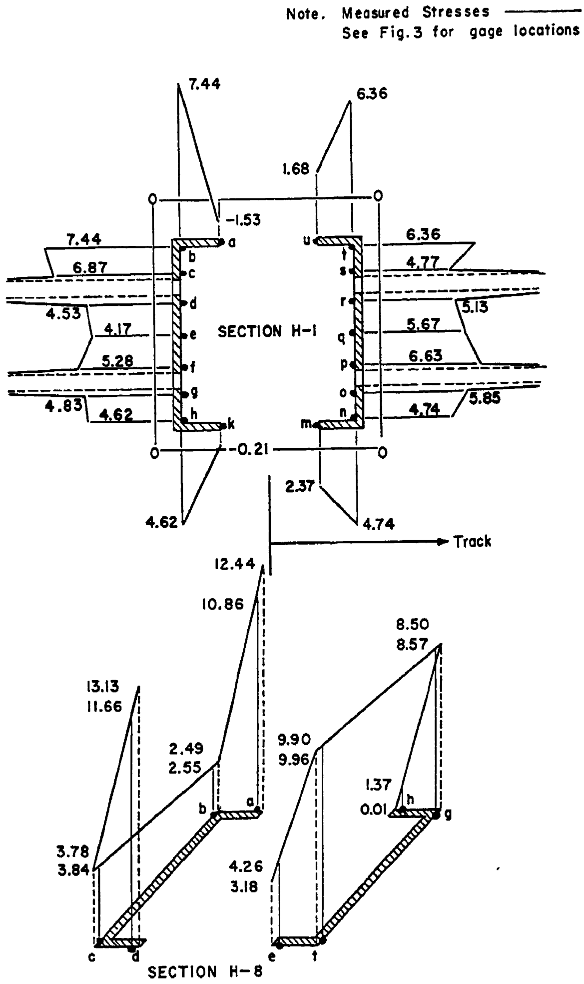


Fig. 5.—Measured Stresses in Floorbeam Hangers U_1 L_1.

The magnetic galvanometer consists of a small mirror, oil damped, suspended on two wires in a permanent magnetic field in such manner that the mirror rotates in proportion to the amount of current flowing through the galvanometer. In general, a current of 4 milli-amperes is required to deflect the light from the mirror 1-in. on the film. The galvanometers have a flat response for frequencies up to 800 cycles per second with a 10-percent loss in response at 1000 cycles per second. In other words, the mirror in the galvanometer will rotate the same amount under a current change applied 800 cycles per second as it does under the current change applied statically.

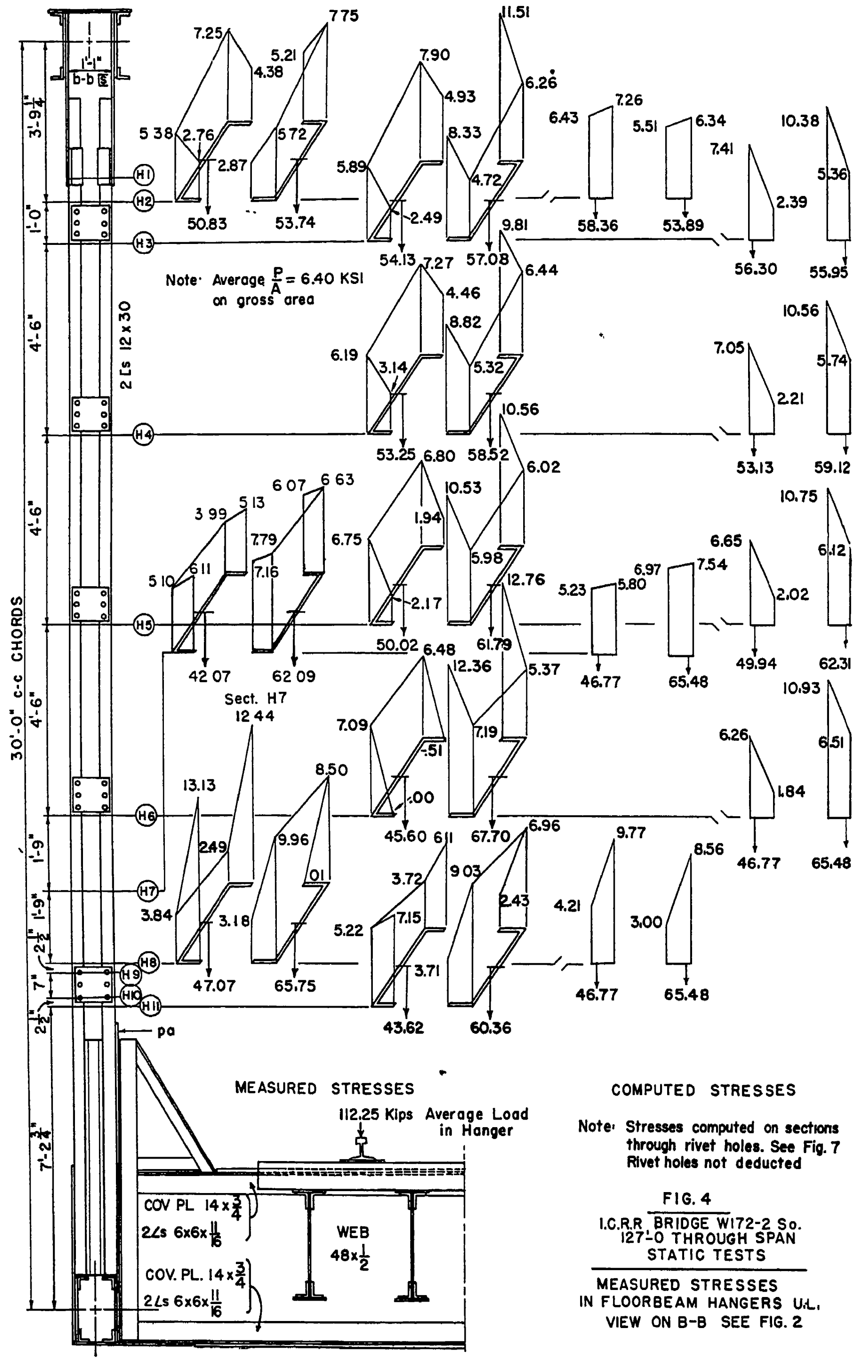


FIG. 4

I.C.R.R. BRIDGE W172-2 So. 127'-0 THROUGH SPAN STATIC TESTS

MEASURED STRESSES IN FLOORBEAM HANGERS U.L. VIEW ON B-B SEE FIG. 2

Analysis of Test Data

Static Tests

The measured static unit stresses on the gross areas due to the live load are shown in Fig. 4. These values are those at the four corners of each channel, and are computed from the strains at gage locations which were ½ in. from the corners. The method of arriving at the corner stresses is shown in Fig. 5, section H–8. For example, the measured unit stresses at the gages are shown in full lines, while the stresses at the corners of the flanges computed from the measured unit stresses are shown in dotted lines. Fig. 4 also shows the total load carried by each channel as computed from the measured unit stresses. For example, at section H–8 the total load carried by the inside channel was 65.75 kips and the total load carried by the outside channel was 47.07 kips. The measured unit stresses at the sections through the rivet holes are shown in Fig. 5, section H–1, and in Fig. 6, sections H–9, H–10.

The principal facts shown by these data are the following:

1. At the top of the floorbeam bracket below section H–11, the load on the inside channel of 60.36 kips is nearly 50 percent greater than the load of 43.62 kips on the outside channel. This excess load on the inside channel is gradually distributed to the outside channel by the tie plates, so that at the top of the hanger, section H–2, the two channels carry almost equal loads of 53.74 and 50.83 kips, respectively.
2. This unequal distribution of load between the two channels sets up racking in the member resulting in the severe bending stresses measured in the field, as shown in sections H–8, H–7, H–6 of Fig. 4.
3. The measured bending stresses on gross areas at the gage sections run as high as 100 percent of the average axial unit stress in the member as a whole. For example, the average measured axial unit stress in the hanger as a whole at section H–8 is 6.43 ksi. and the maximum measured bending unit stress in the outside channel is 6.70 ksi. The gage sections are 2½ in. from the points of maximum moment in the channels (i.e., through the rivet lines at the top and bottom of the tie plates) and the bending stresses at these points of maximum moment must be even more than 100 percent, particularly when it is recalled that the effect of the rivet holes will be to increase the stresses materially. In short, the maximum unit stresses due to this bending must be well over 100 percent of the average axial unit stresses.
4. These local bending stresses occur at all the tie plates. Being due to racking caused by the difference in load in the individual channels, they are most severe at the lower end of the hanger where the difference in the load carried by each channel is the greatest.
5. Hangers composed of two rolled or built channels having no connection with each other except occasional tie plates act for the most part as two individual channels and not as a unit.
6. For such construction the stress distribution across the member does not vary as a plane.
7. When the floorbeam bends, the bracket on top of the floorbeam pulls the hanger at that point in towards the track and causes added bending.
8. The character of the bending moments in the channels at the top of the floorbeam (i.e., at section H–11) shows that eccentric loading occurs on the inside channel.

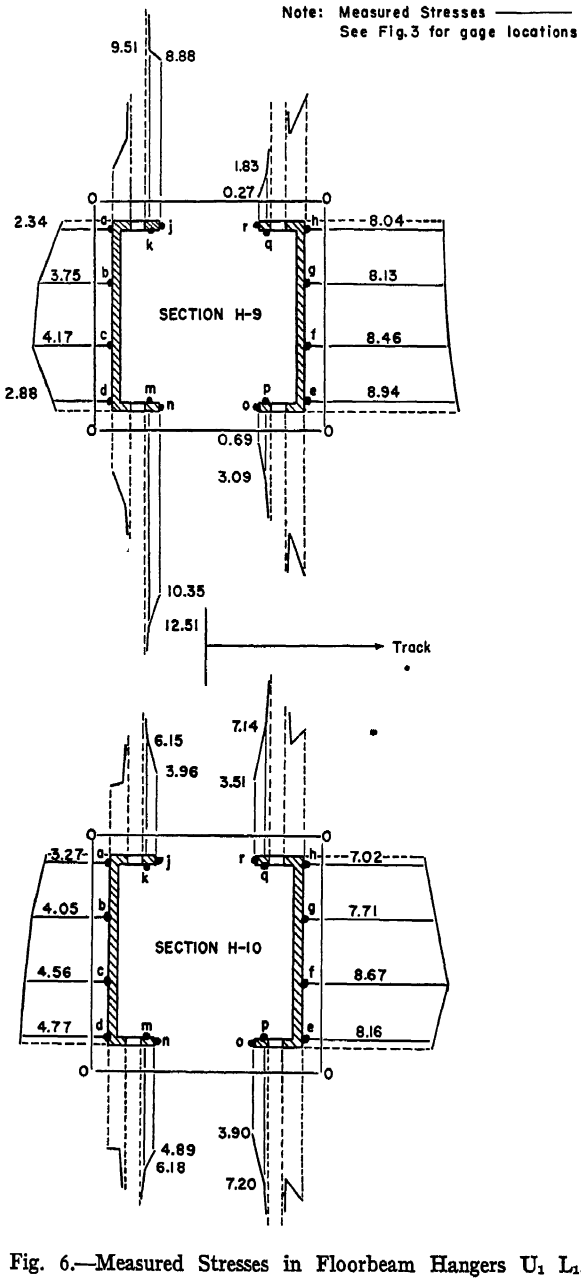
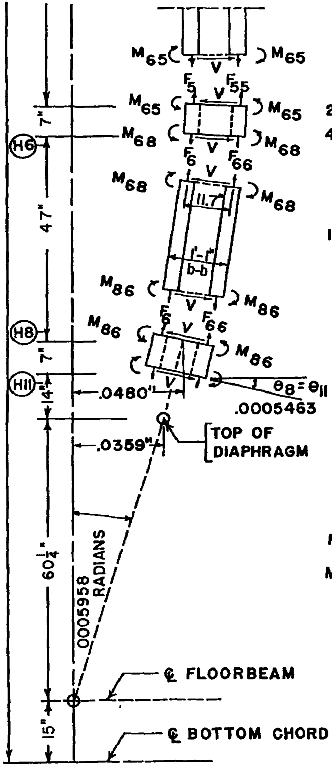


Fig. 6.—Measured Stresses in Floorbeam Hangers U_1 L_1.



$M_{65} = 424\ \Delta_{56} - 13276\ \theta_6 - 6638\ \theta_5$

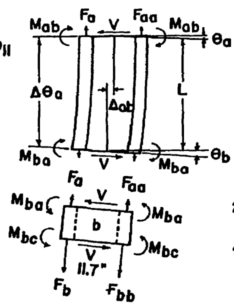
2. $\Delta_{56} - \Delta_{68} - 23.48\ \theta_5 = -0.01283$

4. $F_5 - F_6 + 94\ \Delta_{56} + 72.48\ \Delta_{68} - 1642\ \theta_5 - 5046\ \theta_6 = 0.6201$

$M_{68} = 424\ \Delta_{68} - 13276\ \theta_6 - 3.623$

1. $F_6 - F_{66} - 65645\ \theta_6 + 35.86 = 0$ $\qquad \theta_8 = .0005463$

$M_{86} = 424\ \Delta_{68} - 6638\ \theta_6 - 7.246$



CONDITION EQUATIONS

1. $\Delta\theta_a = \theta_b - \theta_a = \left[\frac{F_{aa} - F_a}{8.79E}\right]\frac{L}{11.70} = \frac{(F_{aa} - F_a)L}{102.843E}$

$M_{ab} = 2E\frac{I}{L}\left(\frac{3\Delta_{ab}}{L} - 2\theta_a - \theta_b\right)$

2. $\Sigma H = 0 = \frac{2(M_{ab} + M_{ba})}{L} - \frac{2(M_{bc} + M_{cb})}{L} = 2\left[2E\frac{5.2}{L^2}\left(\frac{6\Delta_{ab}}{L} - 3\theta_a - 3\theta_b\right)\right] - 2\left[2E\frac{5.2}{L^2}\left(\frac{6\Delta_{bc}}{L} - 3\theta_b - 3\theta_c\right)\right]$

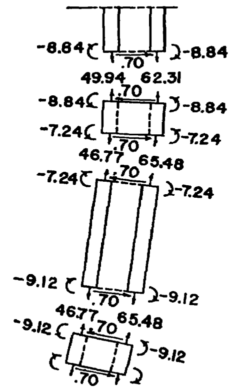
4. $\Sigma M = 0 = 2M_{ba} + 2M_{bc} + 7V + 11.7(F_a - F_b) = 2\left[2E\frac{5.2}{L}\left(\frac{3\Delta_{ab}}{L} - 2\theta_b - \theta_a\right)\right] + 2\left[2E\frac{5.2}{L}\left(\frac{3\Delta_{bc}}{L} - 2\theta_b - \theta_c\right)\right]$
$+ 14\left[2E\frac{5.2}{L^2}\left(\frac{6\Delta_{ab}}{L} - 3\theta_a - 3\theta_b\right)\right] + 11.7(F_a - F_b)$

3. $\Sigma\Delta + 7(\Sigma\theta) = -.0480$

5. $\Sigma\Delta\theta = \theta_8 = .0005463$

6. $F_a + F_{aa} = 112.25^K$

G. SOLVE (4),(5) AND (6) SIMULTANEOUSLY FOR F6.



COMPUTED STRESSES

FIG. 7

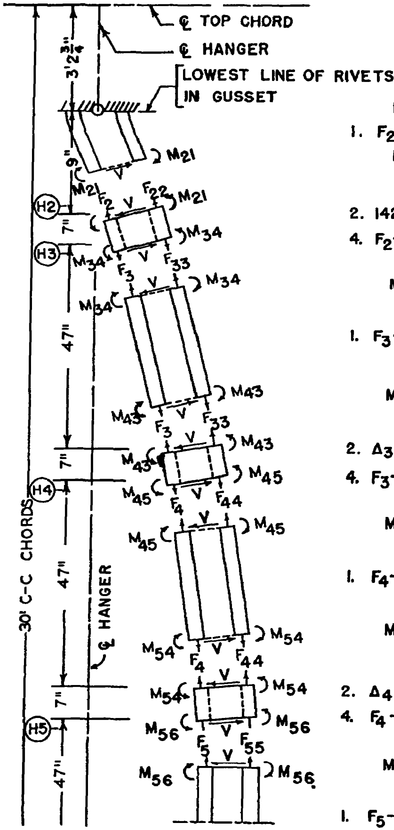
I.C.R.R. BRIDGE W172-2So.
127'-0 THROUGH SPAN
STATIC TESTS

THEORETICAL ANALYSIS
EQUATIONS AND STRESSES

Note: Forces in kips
Moment in inch-kips

Sign Conventions: Angles θ and Δ/L are positive when generated in a clockwise direction. End moments in members are positive when the moment tends to rotate the joint (not the member) in a clockwise direction.

(7b)



EQUATIONS

$$M_{12} = 11555\ \Delta_{12} - 34666\ \theta_3$$

1. $F_2 - F_{22} - 342810\ \theta_3 = 0 \qquad \theta_2 = \theta_3$

$$M_{21} = 11555\ \Delta_{12} - 69333\ \theta_3$$

2. $142.3\Delta_{12} - \Delta_{34} - 616.9\theta_3 + 23.48\theta_4 = 0$

4. $F_2 - F_3 + 5048\Delta_{12} + 72.48\Delta_{34} - 27949\theta_3 - 1135\theta_4 = 0$

$$M_{34} = 424\ \Delta_{34} - 13276\ \theta_3 - 6638\ \theta_4$$

1. $F_3 - F_{33} + 65645(\theta_4 - \theta_3) = 0$

$$M_{43} = 424\ \Delta_{34} - 13276\ \theta_4 - 6638\ \theta_3$$

2. $\Delta_{34} - \Delta_{45} + 23.48(\theta_5 - \theta_3) = 0$

4. $F_3 - F_4 + 94\Delta_{34} + 72.48\Delta_{45} - 1642\theta_3 - 5046\theta_4 - 1135\theta_5 = 0$

$$M_{45} = 424\ \Delta_{45} - 13276\ \theta_4 - 6638\ \theta_5$$

1. $F_4 - F_{44} + 65645(\theta_5 - \theta_4) = 0$

$$M_{54} = 424\ \Delta_{45} - 13276\ \theta_5 - 6638\ \theta_4$$

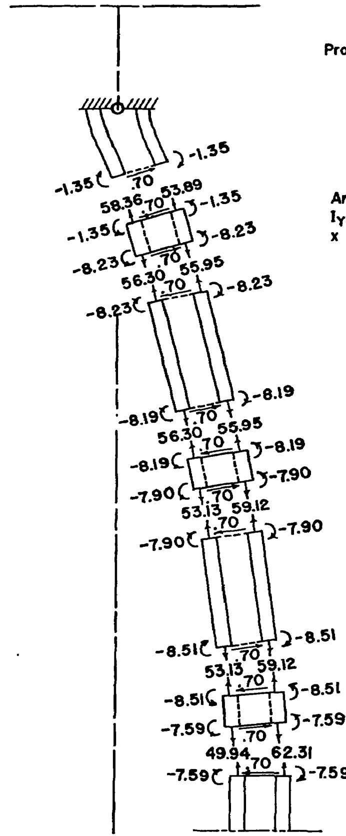
2. $\Delta_{45} - \Delta_{56} + 23.48(\theta_6 - \theta_4) = 0$

4. $F_4 - F_5 + 94\Delta_{45} + 72.48\Delta_{56} - 1642\theta_4 - 5046\theta_5 - 1135\theta_6 = 0$

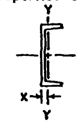
$$M_{56} = 424\ \Delta_{56} - 13276\ \theta_5 - 6638\ \theta_6$$

1. $F_5 - F_{55} + 65645(\theta_6 - \theta_5) = 0$

(7a)



Properties of 12[30



Area = 8.79 in^2
I_{Y-Y} = 5.2 in^4
x = 0.68 in

EQUATIONS

NO		FORCES										ΔS					θS				CONSTANT
		F_2	F_{22}	F_3	F_{33}	F_4	F_{44}	F_5	F_{55}	F_6	F_{66}	Δ_{12}	Δ_{34}	Δ_{45}	Δ_{56}	Δ_{68}	θ_3	θ_4	θ_5	θ_6	
Δθ	θ_8									1	-1									-65645	-3586
	θ_6							1	-1										-65645	65645	0.0
	θ_5					1	-1											-65645	65645		0.0
	θ_4			1	-1												-65645	65645			0.0
Δ	Δ_{68}															1	8.89	13.46	13.46	-10.02	-0.00231
	Δ_{56}														1		8.57	13.46	-10.02	-10.02	-0.01523
	Δ_{45}													1			8.57	-10.02	-10.02	13.46	-0.01523
	Δ_{34}												1				-14.91	-10.02	13.46	13.46	-0.01523
	Δ_{12}											1					-4.44	0.0946	0.0946	0.0946	-0.000107
	G									1			-23.52	-65.16	-106.79	-54.36	-7795	2083	4038	4352	51.18
ΣM = 0	M_6							1		-1					94.07	72.48			-1642	-5046	0.6201
	M_5					1		-1						94.07	72.48			-1642	-5046	-1135	0.0
	M_4			1		-1							94.07	72.48			-1642	-5046	-1135		0.0
	M_3	1		-1								5048	72.48				-27,948	-1135			0.0
ΣF = 0	F_6									1	1										112.25
	F_5							1	1												112.25
	F_4					1	1														112.25
	F_3			1	1																112.25
	F_2	1	1																		112.25

SOLUTION OF EQUATIONS BY SUCCESSIVE APPROXIMATIONS

TRIAL	F_2	F_{22}	F_3	F_{33}	F_4	F_{44}	F_5	F_{55}	F_6	F_{66}	Δ_{12}	Δ_{34}	Δ_{45}	Δ_{56}	Δ_{68}	θ_3	θ_4	θ_5	θ_6
1	56.60	55.65	55.20	57.05	54.08	58.17	51.08	61.17	46.15	66.10	-.000153	-.01945	-.01736	-.01226	-.00139	-.0000028	.0000254	.0000878	.0002416
2	58.61	53.64	56.47	55.78	53.16	59.09	49.88	62.37	46.65	65.60	-.000189	-.02005	-.01814	-.01154	-.00017	-.0000144	-.0000246	.0000662	.0002570
3	58.21	54.04	56.24	56.01	53.11	59.14	49.98	62.27	46.85	65.40	-.000192	-.02015	-.01807	-.01152	-.00038	-.0000121	-.0000155	.0000766	.0002637
4	58.41	53.84	56.33	55.92	53.14	59.11	49.95	62.30	46.74	65.51	-.000196	-.02009	-.01810	-.01154	-.00029	-.0000133	-.0000195	.0000717	.0002601
5	58.36	53.89	56.30	55.95	53.13	59.12	49.94	62.31	46.77	65.48	-.000195	-.02009	-.01808	-.01153	-.00032	-.0000130	-.0000183	.0000729	.0002611

BASIC EQUATIONS FOR ΣH = O AT RIGID BLOCKS

		Δ'S					θ'S				= K
		Δ_{12}	Δ_{34}	Δ_{45}	Δ_{56}	Δ_{68}	θ_3	θ_4	θ_5	θ_6	
ΣH = O	V_3	142.3	-1				-616.9	23.48			0.0
	V_4		1	-1			-23.48		23.48		0.0
	V_5			1	-1			-23.48		23.48	0.0
	V_6				1	-1			-23.48		- 0.01283
	ΣΔ	1	1	1	1	1	7	7	7	7	- 0.0480

PROCEDURE FOR SUCCESSIVE TRIALS

1. ESTIMATE FORCES FROM MEASURED STRAINS FOR TRIAL 1, AND FROM PRECEDING STEPS FOR FOLLOWING TRIALS.
2. COMPUTE θS FROM Δθ EQUATIONS.
3. COMPUTE ΔS FROM Δ EQUATIONS.
4. COMPUTE F6 FROM G EQUATION.
5. COMPUTE FORCES F2, F3, F4, F5 FROM EQUATIONS ΣM=O.
6. COMPUTE FORCES F22 ETC. FROM EQUATIONS ΣF=O.

NOTE: BASIC EQUATIONS FOR ΣH=O AT RIGID BLOCKS WERE SOLVED SIMULTANEOUSLY TO OBTAIN Δ EQUATIONS GIVEN IN EQUATION TABLE ABOVE.

Fig. 8.—Computed Stresses in Hangers; Equations and Solutions.

9. Since the stringers in the adjacent panels were loaded about equally to secure the maximum load in the hanger in these tests, no information was secured regarding the effect of stringer deflection upon bending in the hanger.

In order to account for the measured stress distribution in a rational manner, a theoretical analysis of this frame has been made upon the following assumptions:

1. The computed linear and angular deflection of the hanger at the top of the floorbeam bracket, due to floorbeam bending, is assumed to be correct.
2. The channels are considered fixed at the lower lines of rivets connecting them to the U_1 gussets (i.e., at section H–1) Fig. 9.
3. Each small block represented by the tie-plated section, fastened together with six rivets per tie plate, may be considered to be a rigid unit, compared to the flexible channels. Any flexure or distortion inside this block is neglected.
4. The effect of shearing deflection is neglected.
5. The channels are then subjected to moments arising from rotation of these blocks and from differential horizontal deflections of the blocks in addition to the direct forces.
6. The local effects of the eccentric connections of the channels to the upper gussets, and of the floorbeam to the back of the inside channel are neglected.
7. The logical conclusion from the above is that the computed moments in the two channels at a given horizontal section will be equal.

The geometry assumed above and the corresponding equations together with the computed moments and forces are shown in Fig. 7, a, b. The solution of the equations by successive approximations is given in Fig. 8. The computed deflection and moment diagrams are shown in Fig. 9. A comparison of measured and calculated total loads and extreme fiber unit stresses in the channels is given in Fig. 10. The calculated unit stresses are also shown in Fig. 4. It will be noted that in general the agreement is good and it is believed that this analysis largely explains the structural action found in the hangers.

In Fig. 10, the computed axial unit stresses are obtained by dividing the total axial force in each channel shown in Fig. 7 by the gross area of the channel. The computed bending unit stresses are obtained by dividing the moments at the ends of the channels of Fig. 9 by the gross section modulus of the channel. The measured axial unit stresses are obtained by dividing the total measured force in each channel shown in Fig. 4 by the gross area of the channel. The measured bending unit stresses are obtained by taking the difference between the measured average extreme fiber unit stresses of Fig. 4 and the measured axial unit stresses. The properties of the channel are shown in Fig. 7.

It should be noted that all of the computed unit stresses shown in Figs. 4 and 10 are based upon the gross section of the channels, no deductions being made for holes.

Further attention is directed, however, to the fact that in the lower part of the hanger, notably at sections H–8 and H–6, the measured stresses are considerably in excess of those calculated stresses. (See Fig. 10.) This fact appears to have some significance and receives further study below.

Dynamic Tests

Fig. 12 shows the total stresses at sections H–2, H–6, H–7, and H–8, measured under dynamic loading for selected runs compared with static stresses. The former are shown in dotted lines and the latter in full lines. The dynamic stresses in Fig. 12 are not neces-

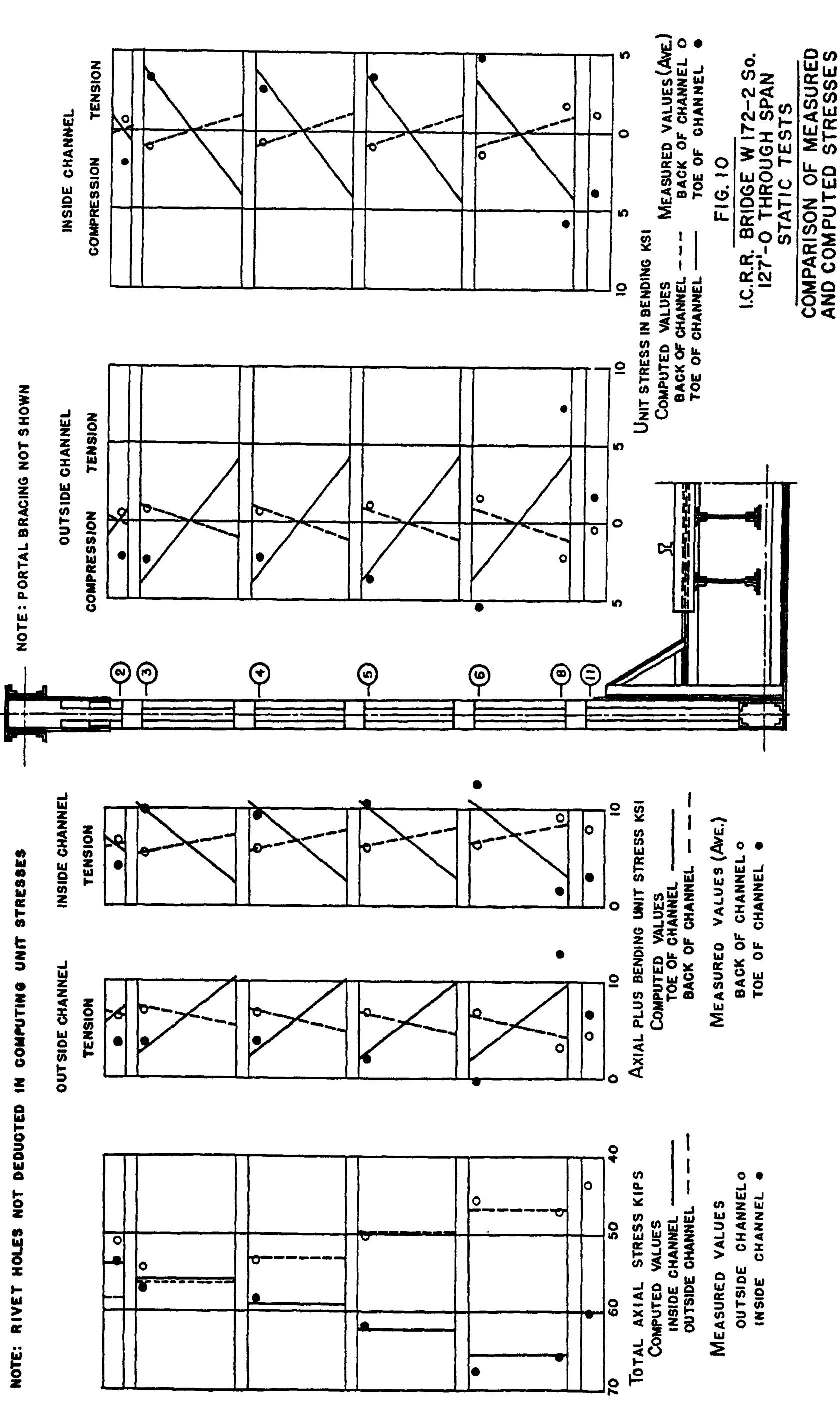


FIG. 10

I.C.R.R. BRIDGE W172-2 So.
127'-0 THROUGH SPAN
STATIC TESTS

COMPARISON OF MEASURED AND COMPUTED STRESSES

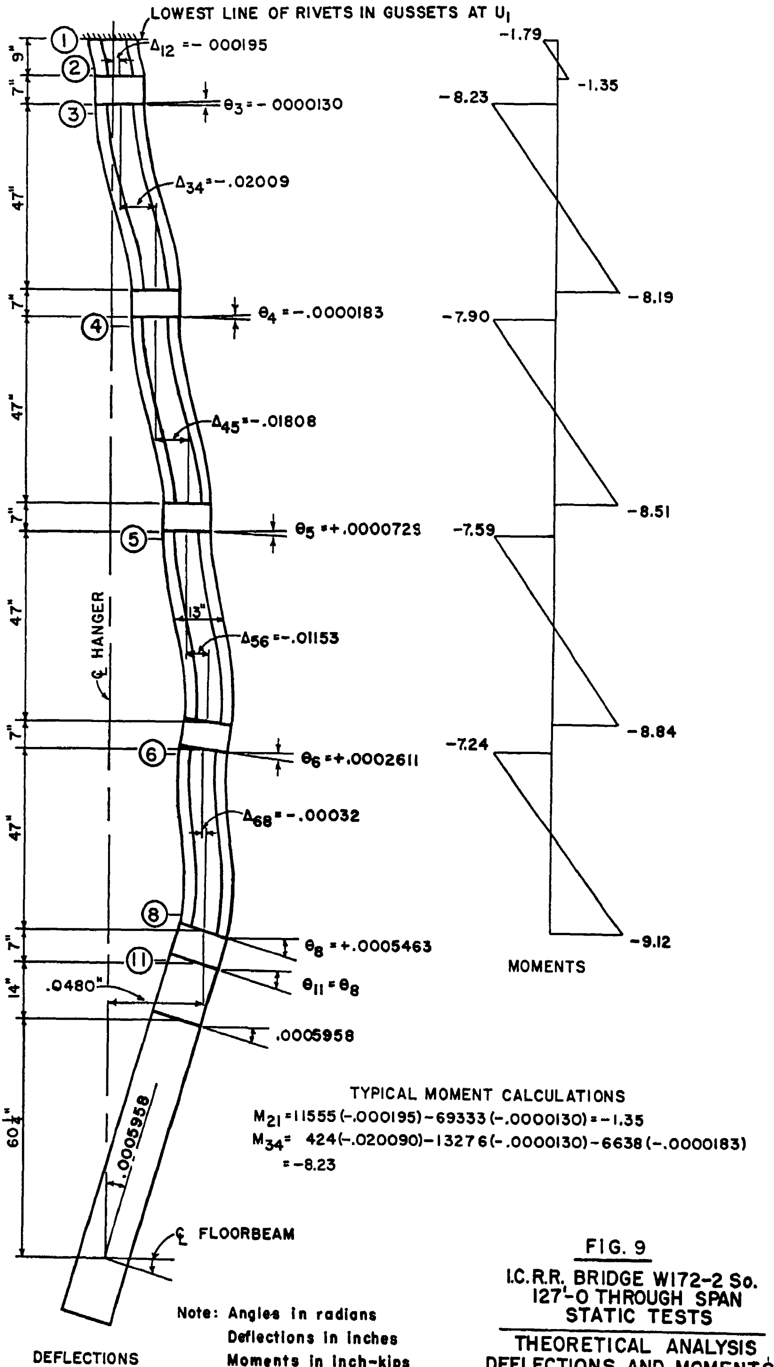


FIG. 9

I.C.R.R. BRIDGE W172-2 So.
127'-0 THROUGH SPAN
STATIC TESTS

THEORETICAL ANALYSIS
DEFLECTIONS AND MOMENTS

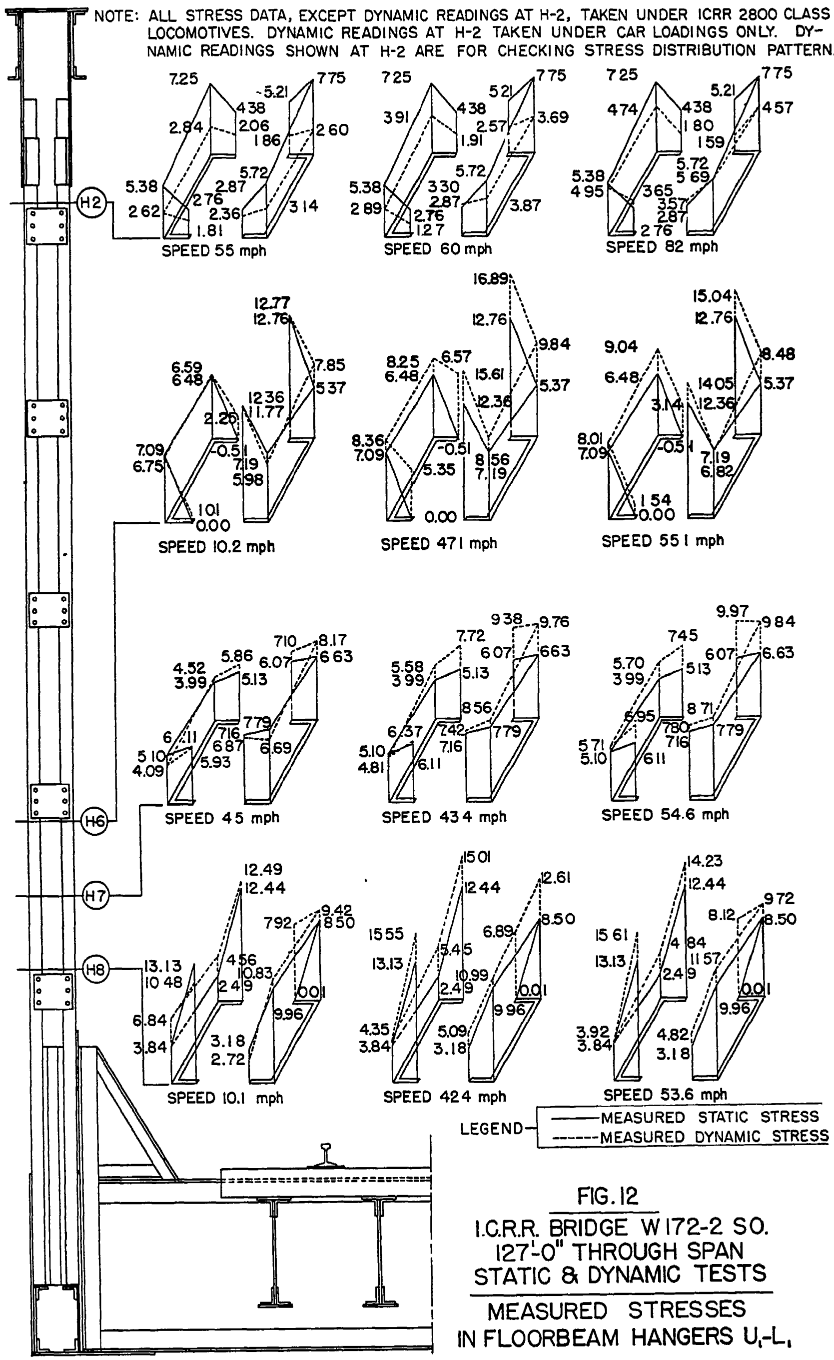


FIG. 12

I.C.R.R. BRIDGE W172-2 SO.
127'-0" THROUGH SPAN
STATIC & DYNAMIC TESTS

MEASURED STRESSES
IN FLOORBEAM HANGERS U_1-L_1

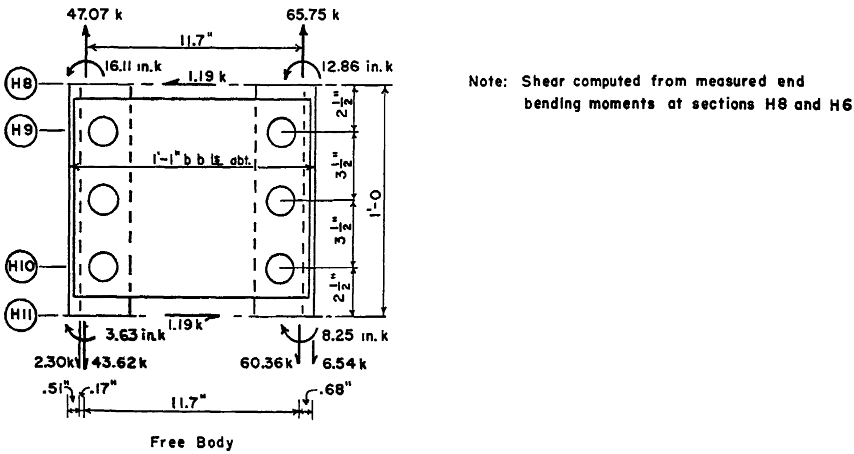


Fig. 11.—Equilibrium Block Between Sections H-8 and H-11 under Measured Forces.

sarily the maximum values recorded. Table 1 gives the impact percentages represented by the stresses shown in Fig. 12. Fig. 13 shows the total impact in the hanger for all the runs made under the Class 2800 engines of the Illinois Central.

In almost all cases, the same gages were used for measuring both the static and dynamic stresses. Thus, since the gage points are identical in both cases, the stresses measured on the section under both types of loading are directly comparable. Wheel-positioning trips on the rail provided a means of synchronizing the position of the train at any instant with the stress occurring at that instant. Also, the wheel trips furnished a means of determining the exact speed of the train.

All of the dynamic runs reported here were recorded under I. C. freight trains hauled by a Class 2800 locomotive. Since the static tests were made using the same class of engine, the data presented in Fig. 12 (except at H–2) are all samples from runs where this class locomotive was used. In all cases, it was found that the maximum stresses recorded occurred under the locomotive when the third driver was directly over the floorbeam at L_1. This corresponds exactly to the loading position used in the static tests. Fig. 12, (except at H–2), indicates a comparison of the maximum measured stresses under a 2800 Class locomotive under both static and dynamic conditions.

At H–2 no readings were obtained under locomotives for direct comparison. Readings were taken under car loadings and these are shown to indicate the stress patterns at this point.

The conclusions from the data studied are:

1. The stress distribution pattern under both static and dynamic loadings is essentially the same. The dynamic stresses merely are larger by some fixed percentage in any specific case.

2. The stresses at 5 mph. agree well with the static stresses.

3. No excessive impact factors (based upon the total load in the member) were noted at any of the sections analyzed. The impact percentages shown in

Interpretation of Test Results

Relations at Connection of Floorbeam to Hanger

One of the main problems involved in the hanger design, and indeed in the design of any truss joint where a floorbeam frames into the near gusset, is the transfer of half of the floorbeam load to the far side of the truss. The difficulties involved are graphically illustrated by the stress relations shown in Fig. 11.

Attention is directed to the stress distribution measured in the channels at sections H–8 and H–11, as shown in Figs. 4 and 5. The stresses at H–8 are easily understood. The moments at H–11, however, are opposite in sign to the moments which would be produced by the constant horizontal shear, estimated at 0.70 kips in the analysis, acting on the hanger above the floorbeam brackets. Furthermore, the moments acting on the channels at H–11, as computed from the stress distribution in Fig. 4, will not balance the other moments acting on the block enclosed by sections H–8 and H–11. Also, the total vertical forces in the channels at H–11 as shown in Fig. 4, are less than the vertical forces acting on the channels at H–8. The whole problem is clear when it is realized that the load on the inside channel is delivered to the back of the channel by the floorbeam connection and that less than half of this amount is carried over to the outside channel by the diaphragm. The force on the back of the inside channel sets up a bending moment of the character measured. Furthermore, the stresses shown in Fig. 4 are derived from gages near the flanges only, since at H–11 no other gages were used. The fill plate *pa,* however, which extends up the face of the inside channel above the floorbeam bracket undoubtedly delivers considerable extra load in the middle of the channel which would produce, locally, greater stress than that shown in Fig. 4. Evidence of this is seen in the readings in this channel at section H–10 some 2½ in. above the place where gages were placed in the middle half of the back of the channel. (See Fig. 6.)

This added load, delivered by *pa* to the back of the channel just below H–11, is what is required to make both vertical forces and moments on this (H–8) — (H–11) block balance. It also seems probable that a vertical deflection of the inside channel relative to the outside channel occurs below H–11 due to shearing stresses in the diaphragm web. While the shearing stresses are low, the resulting deflection would produce a further rotation at H–8 of about 10 to 15 percent of the value computed in the theoretical analysis. The above factors are what are needed to account for the overrun of the measured stresses over the stresses computed above. They also account for the magnitude and sign of the bending moment in the inside channel at H–11. The moment in the outside channel is about what can be computed by the angle change between section H–11 and a section at the top of the diaphragm, assuming this angle change to be due to the greater unit axial stress in the inside channel, and to the shearing deflection just discussed. The moments at this section which would be due to transverse shear are relatively small compared to the effects just discussed.

The stress relations observed above make it clear that this problem cannot be solved merely by the use of a substantial diaphragm at the end of the floorbeam connection, since the diaphragms used in the Galena hangers are quite substantial. The calculated unit shearing stress in the diaphragm web is less than 2 ksi. What is necessary, clearly, is adequate shear bracing connecting one segment or channel of the hanger to the other. It is also evident that such shear bracing should extend without interruption for the full length of the hanger as, otherwise, heavy local bending stress will occur at the section where the bracing is eliminated, just as it occurs here.

TABLE 1.—RECORDED IMPACTS IN HANGER
(See Fig. 12 for location of sections.)

SECTION	SPEED (MPH)	% IMPACT AT PARTICULAR GAGE POINT HAVING MAX. STATIC STRESS	% IMPACT BASED UPON MAX. LOAD IN INDIVIDUAL CHANNEL	% IMPACT BASED UPON TOTAL LOAD IN HANGER MEMBER
COLUMN 1	2	3	4	5
H 6	10.2	0.1	5.8	5.6
	47.1	32.4	49.2	44.0
	55.1	17.9	36.6	26.7
H 7	4.5	23.2	3.5	1.1
	43.4	47.2	38.5	31.8
	54.6	48.4	29.9	28.4
H 8	10.1		31.3	24.9
	42.4	18.4	39.6	38.2
	53.6	18.0	29.2	22.5

ALL DATA TAKEN UNDER ICRR 2800 CLASS LOCOMOTIVES

NOTES: COLUMN 3 GIVES VALUES FOR $\frac{\text{(DYNAMIC STRESS AT POINT} - \text{STATIC STRESS AT POINT)}}{\text{(STATIC STRESS AT POINT)}}$

COLUMN 4 GIVES VALUES FOR $\frac{\text{(TOTAL DYNAMIC LOAD IN CHANNEL} - \text{TOTAL STATIC LOAD IN CHANNEL)}}{\text{(TOTAL STATIC LOAD IN CHANNEL)}}$

COLUMN 5 GIVES VALUES FOR $\frac{\text{(TOTAL DYNAMIC LOAD IN MEMBER} - \text{TOTAL STATIC LOAD IN MEMBER)}}{\text{(TOTAL STATIC LOAD IN MEMBER)}}$

Fig. 13 are all less than those provided by the present AREA design specifications.

4. The extreme fiber stress (due to live load, impact, bending, and racking) as actually measured at a particular point is sometimes nearly three times as high as the "average" live load stress computed by usual design methods. This average axial static live load stress, computed from the engine diagram is 6.5 ksi., as compared with the measured value of 6.4 ksi. (See Fig. 4.)

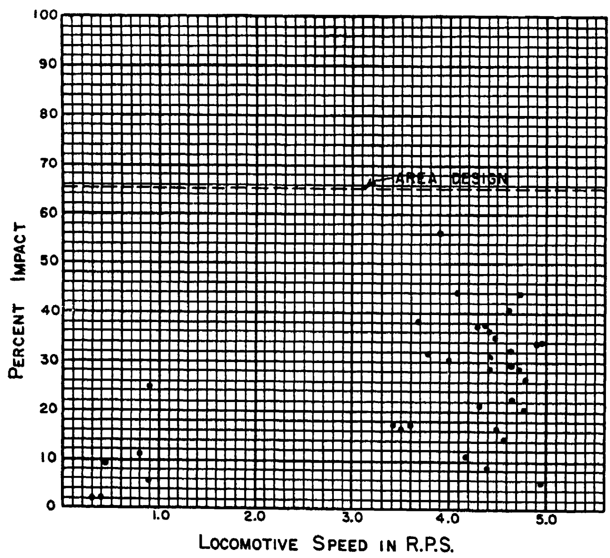


Fig. 13.—Total Impact in Hanger $U_1 L_1$ under Class 2800 Locomotive.

Conclusions

Stress Distribution in the Hanger Due to Floorbeam Deflection

1. The large eccentricity of loading in the hanger due to the delivery of the floorbeam reaction to the inside gusset sets up severe local stresses and also causes shear as well as moment throughout the entire length of the hanger.

2. The rotation and transverse displacement of the end of the hanger at the top of the floorbeam or floorbeam bracket due to floorbeam deflection both set up added bending stresses in the hanger which are considerable.

3. The upper end of the hanger was found to be fixed against displacement and rotation for all practical purposes. This fixity is undoubtedly due in part to the very stiff portal bracing of the end post.

Stress Distribution in the Hanger Due to Form of Section

1. This hanger, composed of two channels or segments having no connection with each other except occasional tie plates, does not act as a unit, but as two individual members which are subjected to severe racking stress.

2. This racking is due fundamentally to the lack of adequate shear bracing for the hanger section, and occurs as load is transferred from the inside channel to the outside channel.

3. This racking sets up severe bending stresses in the hanger. Such bending stresses were as high as 100 percent of the axial unit stresses in the Galena bridge.

4. The severe local stresses in the hanger above the diaphragm opposite the floorbeam are evidence that this detail does not satisfactorily distribute the floorbeam reaction to the hanger channels.

5. While all of the stresses measured in these hangers can be accounted for in a rational manner, a satisfactory design of a floorbeam hanger frame using this type of section does not seem practicable for the following reasons: The relative stiffness of the hanger, the distribution of load between the channels by the tie plates, and the distribution of load between the channels at the top of the floorbeam bracket are all very uncertain.

6. In order to insure that the parts of a hanger will act as a unit, adequate shear bracing is essential.

Fatigue Strength

Stresses of the intensity measured here will undoubtedly reduce the fatigue strength of the member very materially.

Form of Section

In general, hangers or main components of hangers should be tied together with continuous and unbroken bracing throughout the length of the members.

Acknowledgment

The Committee on Iron and Steel Structures and the American Railway Engineering Association are indebted to the officers of the Illinois Central Railroad for their cooperation in conducting these tests.

Transverse Displacement of Hanger at Floorbeam

The fact that the horizontal displacement of the hanger at the top of the floorbeam due to floorbeam deflection is of sufficient magnitude to set up considerable bending stresses in the hangers should be noted.

Lug or Clip Angle Connections

Some light is thrown on the efficiency of lug or clip angle connections by the measured stress distribution at sections H-1 and H-2, shown in Fig. 4. These tests show that while these angles carry a considerable stress from the flanges to the gussets, they are far from 100 percent efficient since these sections show considerable bending. Undoubtedly what is required is an excess of rivets in one leg of the clip angle so that all possibility of slip is eliminated.

Fundamental Relations

The outstanding fact shown by these tests, both static and dynamic, is that for floorbeam hangers composed of elements not adequately braced or tied together for shear, a plane section before bending does not remain a plane section after bending. This has important implications.

1. The actual stresses will bear little relation to stresses computed on the usual assumptions. In most cases, the actual stresses may be expcteed to be much larger than the computed stresses.

2. In making strain gage studies, gages should be placed at enough points in a given section to secure an accurate picture of stress distribution in each element of the section.

3. When the above precaution is followed, the total measured stress in a given member should check closely with the known loads.

Stresses on Sections through Rivet Holes

Sections H-1, H-9, H-10, in Figs. 5 and 6, taken through rivet holes show interesting stress patterns. The ¼-in. gages used could not be placed closer to the edge of the hole than about ¼ in. Consequently it was not possible to measure the large local stress which occurs at the edge of the hole. However, the stresses obtained show clearly the great variation in stress across a section which occurs locally along a line of rivets.

Effect of Form of Section Upon Fatigue Strength

It seems evident that the serious bending stresses which occur in this type of member must be highly undesirable in a floorbeam hanger from the standpoint of fatigue strength for the following reasons:

1. The stresses are a maximum on sections through the rivet holes.

2. The racking at these sections is always in the same direction and recurs under the passage of every live load. This results in a wide range of stress, since the dead load stress is small.

3. It is probable that additional stress concentrations occur at the rivet holes where end rivets in the tie plates resist the bending in the channels at these points, due to rivet bearing.

the foremost designing and consulting engineers of the country to discuss and plan the various projects. All of these men have given most liberally of their time and knowledge in carrying forward the work of the council. The organizations forming this council and their representative members are:

Sponsor	*Representative*
1. American Bridge Company	C. E. Webb, Chief Engineer
2. American Institute of Steel Construction	T. R. Higgins, Director of Engineering—Jonathan Jones, Chief Engineer, Fabricated Steel Construction, Bethlehem Steel Co.
3. American Iron and Steel Institute	B. L. Wood, Consulting Engineer—Samuel Epstein, Research Engineer, Bethlehem Steel Co.
4. American Society of Civil Engineers	J. I. Parcel, Consulting Engineer, Sverdrup & Parcel
	W. M. Wilson, Research Professor of Structural Engineering, University of Illinois
5. Association of American Railroads	G. M. Magee, Research Engineer
	J. L. Beckel, Assistant Engineer of Structures, New York Central Railroad
	C. H. Sandberg, Assistant Bridge Engineer, Atchison, Topeka & Santa Fe Railway
6. Bethlehem Steel Company	W. R. Penman, General Manager, Bolt and Nut Department
	Jonathan Jones, Chief Engineer, Fabricated Steel Construction
7. Engineering Foundation	F. T. Sisco, Director
	B. A. Bakhmeteff, Member of Board
8. State of Illinois, Division of Highways	R. B. Murphy, Design Engineer
	L. E. Philbrook, Assistant Bridge Engineer
9. Industrial Fasteners Institute (Formerly American Institute of Bolt, Nut and Rivet Manufacturers)	H. H. Lind, President
	H. C. Graham, Vice-President, Pittsburg Screw & Bolt Corp.
	Wm. C. Stewart, Technical Adviser
10. Northwestern University	Frank Baron, Professor of Civil Engineering
	C. W. Muhlenbruch, Associate Professor of Civil Engineering
	K. H. Lenzen, Research Associate of Civil Engineering†
	E. W. Larson, Jr., Research Associate of Civil Engineering
	C A. Ellis, Professor
11. Public Roads Administration	E. F. Kelley, Chief, Division of Physical Research
	E. L. Erickson, Chief, Bridge Division
	R. Archibald, Chairman, Bridge Committee, American Association of State Highway Officials
12. Purdue University	L. T. Wyly, Professor of Structural Engineering
13. University of California	R. E. Davis, Professor of Civil Engineering
14. University of Illinois	W. M. Wilson, Research Professor of Structural Engineering
	N. M. Newmark, Research Professor of Structural Engineering
	T. C. Shedd, Professor of Structural Engineering
	W. H. Munse, Special Research Assistant Professor of Civil Engineering
15. Woodruff & Sampson Engineers	G. B. Woodruff

† Now at Purdue University.

Progress Report of Research Council on Riveted and Bolted Structural Joints*

The Research Council on Riveted and Bolted Structural Joints was organized on January 15, 1947, in New York City by representatives of organizations and universities particularly interested in the behavior of such joints in structures. The organizing representatives of the council elected T. R. Higgins, director of engineering, American Institute of Steel Construction, as its chairman. An executive committee was organized and the present members are:

(1) T. R. Higgins, chairman
Raymond Archibald
Jonathan Jones
Herman H. Lind
G. M. Magee
J. I. Parcel
W. M. Wilson

The council was formed because it was generally recognized that existing practice in the design of riveted and bolted connections has been empirically developed from experience and that many of these practices are not supported by definite experimental data. The objective of the council is to promote extensive research planned to insure safer and more economical design and construction of metal structures, primarily of steel but not excluding alloys and nonferrous metals. It is the expectation that the work of the council will result in the promulgation of more economical and efficient practices.

At the present time, the council has planned and approved seven projects for study, and considerable progress has been made on six of these investigations. A total of $47,034.08 in direct costs has been expended up to March 31, 1949, on these projects.

The council depends entirely upon organizations interested in the behavior of riveted and bolted structural joints for its direct financial support and the following sponsors have made financial contributions:

1. American Institute of Steel Construction
2. American Iron and Steel Institute
3. Association of American Railroads
4. Engineering Foundation
5. State of Illinois, Division of Highways
6. Industrial Fasteners Institute (formerly American Institute of Bolt, Nut and Rivet Manufacturers)
7. Public Roads Administration

The University of Illinois and Northwestern University have contributed to the council by providing laboratory equipment and the services of university personnel for the investigations.

In addition to financial support, the council is also dependent upon interested organizations for memberships in the council to plan and assist with the various projects undertaken. An important advantage of a council of this type is that it brings together

* Participation by the Association of American Railroads in the work of the council was initiated on the recommendation of Committee 15—Iron and Steel Structures.

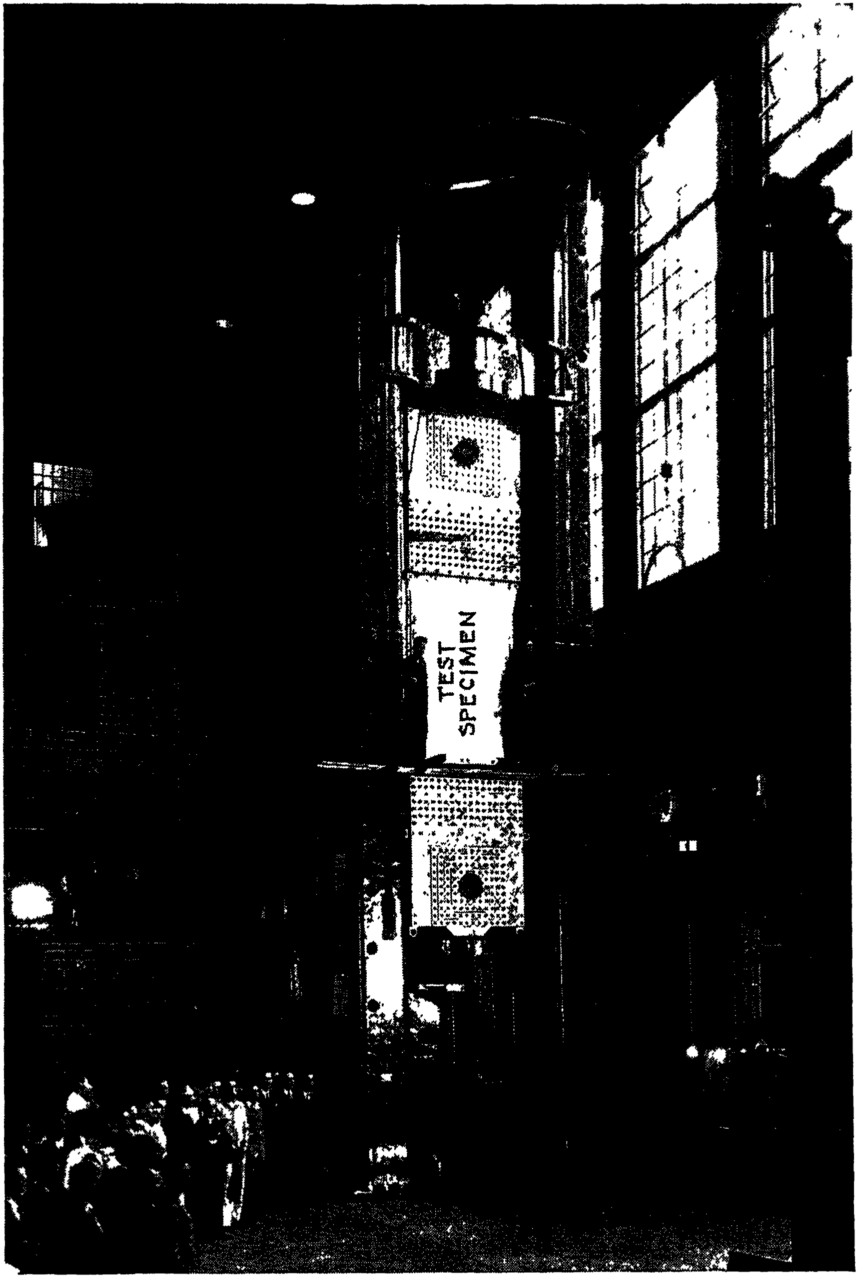


Fig. 1.—3,000,000-lb. Static Testing Machine.

The laboratory work has so far been done by the University of Illinois and Northwestern University where both static and fatigue testing machines having large capacities are available for this work. The static testing machine shown in Fig. 1 has a capacity of 3,000,000 lb. and is located at the University of Illinois. The 2-unit fatigue testing machine shown in Fig. 2 has a capacity of 250,000 lb. tension or compression and is located at Northwestern University. The University of Illinois has two similar machines of 200,000 lb. capacity. Additional fatigue testing machines of smaller capacity are also available at both universities.

The general objective of each project, the laboratory where the tests are being made and the present status of the investigations are:

Project I—Jonathan Jones, Chairman

Effect of bearing pressure on static and fatigue strength of riveted joints.

Talbot Laboratory—University of Illinois.

Standard specifications for design of riveted structures specify, in many connections, that the number of rivets required to resist the failure of the rivets in shear be augmented in order that the bearing pressure between rivet and plate shall not exceed a stipulated intensity. As an example, under standard bridge specifications a single ⅞-in. rivet in double shear is permitted to resist a force of 16,200 lb. if the plate thickness is 11/16 in. or more; but only 14,800 lb. if ⅝ in., 11,800 lbs. if ½ in., and so on. There are accordingly many instances in which the number of rivets, and the size of the connecting gussets or splice plates, must be increased, at added cost, to conform with the prescription for "bearing."

This prescription, however, is arbitrary. It was remarked, in the report on some joint tests made over a generation ago, that it was then "customary" to allow a bearing pressure twice the unit stress in shear. No experimental evidence that such an allowance is more logical than another, has come to light. Therefore it appears profitable to experiment with various bearing-shear ratios to find whether a higher and more economical ratio than 2:1 is justified by the facts.

Project Committee No. 1 has completed several series of pilot tests on joints with hot driven rivets at the University of Illinois under the direction of Professor Wilson, and has a further series now planned. The tests to date have indicated what some of the important variables are, and that certain statements can at least tentatively be made, viz.,

1. "High bearing pressure" is only another way of saying "thin connected material" (thin as related to the diameter of the rivet used); under working loads there may or may not be any actual bearing.

2. A rivet of short grip (driven for example through a certain number of plies of thin material) does not have the clamping force of a rivet of long grip (driven through the same number of plies of thicker material). On geometrical reasoning this should not be so, and it is presumably a function of rivet constitution and head behavior.

3. A rivet of short grip will, as a practical commercial average, fill its hole more closely than a rivet of long grip.

4. Initial slip, which represents the overcoming of friction and which brings actual bearing into existence as its consequence, may therefore start sooner with rivets of short grip (thin material) than with rivets of long grip (thick material); but should proceed over less distance before bringing up in bearing.

5. Slip is of less consequence in static than in fatigue loading.

6. In static loading, after initial slip has been arrested by bearing, three conditions are to be distinguished:

(a) If the critical plate is being stressed in tension, and there is an insufficient distance from the rivet to the end of the piece, failure can occur through the bulging out and ultimate bursting open of the plate, beyond the rivet and in line with the load. (This type of failure is recognized in AISI building specifications, but not in standard bridge specifications).

(b) If the critical plate is being stressed in tension, and there is sufficient end distance, then under ordinary relationships failure will not occur by the crushing of material at the surface in bearing, since this will be preceded by the failure of the plate on a transverse line through the hole or holes (failure in plate tension). Whether, and if so to what extent, such tensile failure is hastened by high bearing, acting as a stress raiser, remains to be completely investigated.

(c) If the critical plate is being stressed in compression, then after initial slip produces actual bearing it is quite possible for thin material to fail by the flowing of the metal at the bearing surface. The safe limit under this condition, and the possibility of different bearing allowances, in tension and in compression, remain to be investigated.

7. In fatigue testing, the rapid intermittent or opposed loading usually produces a rapid increase of heat soon after initial slip occurs. Therefore high bearing stress may be much more destructive in fatigue than in static testing; not because of high bearing in itself but because of the short grips associated with thin material. This is undoubtedly exaggerated in the laboratory as compared with actual service conditions.

The test program for this project during at least the first part of 1949 has been confined to static testing. So many more structural members are subjected to static than to fatigue loading in service, that it has seemed advisable to concentrate first on that portion of the field above outlined.

Project II—W. M. Wilson, Chairman

Effect of rivet pattern on static strength of structural joints.

Talbot Laboratory—University of Illinois.

Static tests of riveted joints connecting structural members have been made, piecemeal, over a period of approximately a century. Nevertheless, the lack of coordination of these tests has resulted in a spotted coverage of the field that leaves many portions untouched and the results in other portions are inconclusive. Also, changes have been made in the types of materials used and in the methods of fabrication. Consequently, structural designers are not in general agreement relative to the most economical rivet pattern to use for a riveted joint of a structural tension member. In fact, a number of engineers whose judgment is worthy of serious consideration are definitely of the opinion that specifications generally used in the design of steel structures put a premium on the use of undesirable rivet patterns.

The determination of a design rule for computing the static strength of riveted structural members more accurate than the ones now in use would, in itself, justify the formation of the research council. The above statements are supported by the following considerations.

Design formulas generally used for riveted joints fail to take into account the influence of the transverse spacing of the rivets on the average unit static strength of the net section of the plates in tension. The *apparent* strength of steel coupons as generally reported is the maximum load divided by the original section of the coupon. For A7 steel, the actual section of the coupon at failure is much less than the original section, and the

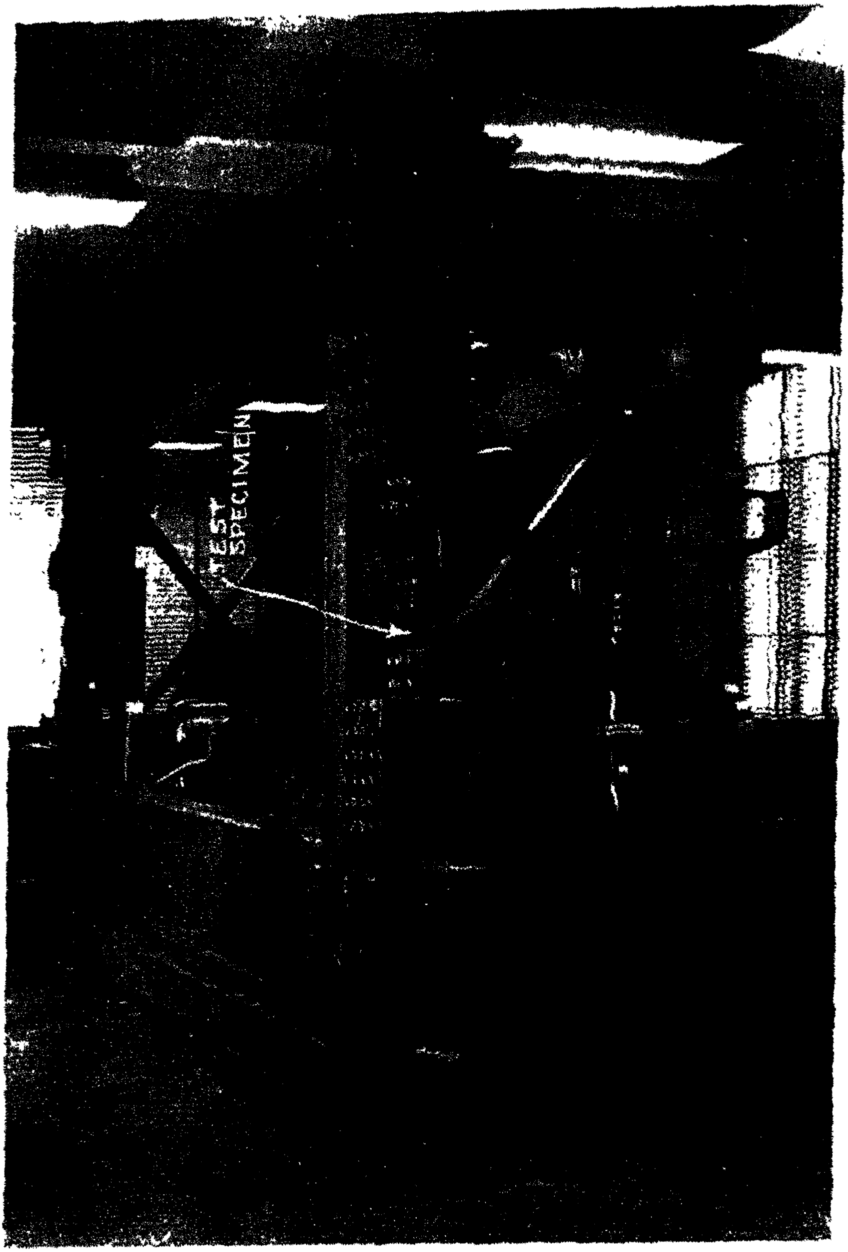


Fig. 2.—250,000-lb. Fatigue Testing Machine.

Project III—T. R. Higgins, Chairman

The strength of rivets in shear and combined shear and tension.

Work on this project has been held in abeyance largely for budgetary reasons. However, the committee is now preparing a program of investigations to be considered by the council.

Project IV—W. C. Stewart, Chairman

Fatigue strength of bolted structural joints.

Talbot Laboratory—University of Illinois.

Exploratory research supports the belief that structural joints fastened with high tensile bolts will demonstrate superior values.

Bolting is simple and economical, especially in field construction, and more particularly in small or remote jobs where the necessary assembly equipment is not readily available. Further, it obviously would be economical to leave erection or fitting-up bolts in place rather than incur the expense of their removal and replacement with rivets, if this procedure were shown to be satisfactory.

Common structural bolts, of course, have been used for many years in certain structures. The present investigation is concerned principally with the different type of behavior under cyclic loading of joints made up under the great clamping force of high-strength bolts, which is some three times that of common bolts. As an example, present specifications for bridges require that the rivets for connections subjected to a complete reversal of stress be designed on the basis of a unit stress on the rivets only one-half as great as the stress allowed for rivets not subjected to a reversal of stress. The result is that the connections for large riveted structural members subjected to a reversal of load are exceedingly large, cumbersome, and expensive. A limited number of reversed-load fatigue tests made on riveted joints for which the tension in the rivets was great enough to resist the load entirely by friction, indicated that the joints were practically unaffected by the reversal of the load. Tests on similar joints with rivets for which the tension in the rivets was not great enough to enable the joint to resist the load by friction, indicated that these joints had a very low fatigue strength. This suggested the possibility of using joints with high-strength bolts, not necessarily filling the holes, which could be given sufficient tension to cause the joint to resist the load by friction.

The manner in which a bolted joint functions depends upon the relation between the tension in the bolts and the shear on the joint. If the bolt tension is great enough relative to the shear, the shear is resisted entirely by virtue of the friction between the plates. Otherwise, the joint will slip and bring the bolts into bearing on the plate. Under the first condition, a fatigue failure of the bolts would seem improbable. Under the second condition, a reversed-load cycle would cause wear on the faying surfaces that would relieve the tension in the bolts and, possibly, cause a fatigue failure of the bolts. For some tests the slip sometimes caused galling which prevented subsequent slip. It would seem probable, therefore, that the effect of a reversed-load cycle on a bolted joint would depend upon the relation between the tension of the bolt, the shear on the joint, and the coefficient of friction of the faying surfaces. Moreover, the few tests that have been made indicate that the relation between the bolt tension and the shear on the joint that produces slip is influenced somewhat by the bolt pattern and the grip of the bolts.

Thirty bolted joints have been tested in fatigue. Some of the results, given in Table 1, are of especial interest. The relation between the bolt, tension and the frictional resistance between the plates, which is the vital relation in considering the feasibility of using bolted joints for the end connections of members subjected to a

true strength (maximum load divided by the section at the time the maximum load is first attained) is greater than the *apparent strength* usually reported. For a plate with holes at frequent intervals the portion of the metal subjected to the maximum stress, the portion between the holes in the outside row, is very short and the reduction of area at maximum load is less than for a long slender standard coupon which has a considerable length of constant section. This action of plates with closely spaced rivets might be expected to increase the unit strength based on the original net section above the coupon strength (also based on the original net section) of the steel from which the plate is made.

In contrast with the above, for riveted joints with widely spaced rivets on the outer row, the stress is unevenly distributed over the portion of the plate between rivets, being greater adjacent to the rivets where fractures originate than at points midway between the rivets. Tests are on record of riveted joints connecting plates cut from the same parent plate for which the transverse spacing of the rivets in the outer row had values of 3 in., 6 in., and 12 in. The ratio of the unit plate strength on the net section to unit coupon strength for the various specimens had values of 1.13, 0.94, and 0.92, respectively.

Nevertheless, the influence of the transverse rivet spacing on the unit strength of the critical section is not taken into consideration in the design formulas in use.

Four groups of tests have already been made on Project II, as follows:

Group 1.—The six specimens of Group 1 each consisted of a riveted joint connecting a 16-in. by ¾-in. plate to two 16-in. by ½-in. plates, the ⅞-in. rivets being in double shear. The ¾-in. plates, which were the parts to fail, were all cut from the same parent plate. Each specimen had a different rivet pattern, the transverse distance between the rivets in the outer row varying from 3 in. to 12 in. These specimens were all tested at room temperature.

Group 2.—The six specimens of Group 2 were identical with the corresponding specimens of Group 1. All of the specimens of Group 2 were tested at subzero temperatures except one which was tested at 118 deg. F. The ultimate strengths of corresponding specimens of the two groups did not differ greatly.

Group 3.—The specimens of Group 3 consisted of lap joints with ¾-in. rivets connecting universal mill plates with rolled edges. For some specimens the plates were 16 in. by ½ in., for others they were 18 in. by ½ in. There were duplicate specimens of each of seven rivet patterns. All specimens were tested at a subzero temperature.

Group 4.—The specimens of Group 4 were butt joints with ¾-in. rivets connecting one 16-in. by ½-in. inside plate to two 16-in. by ⅜-in. outside plates. All plates were universal mill plates with rolled edges. Of two identical specimens, one was tested at approximately + 120 deg. F. and the other was tested at approximately — 20 deg. F.

There have been a total of 38 of the large riveted joints tested in connection with this project. A preliminary study of the data would seem to indicate that several factors enter into the strength of the plates of a riveted joint, other than those provided for by the usual design formulas for net section. For one thing, the condition of the edges sheared or rolled, appears to be an important factor, especially at low temperatures. Further, the results to date appear to indicate that the increase in strength due to an increase in the transverse distance between rivets is less than such formulas indicate.

After the data now available has been carefully analyzed, additional specimens of the general character of those already tested will be designed to close the gaps in the current data. It is hoped that the tests of these specimens will provide data which, analyzed in connection with data already available, will furnish the basis for design formulas more in accordance with the facts than any of the formulas now in use.

In addition to the laboratory fatigue tests that have been made, the research staff of the Association of American Railroads has made several test installations of high strength bolts in bridges on various railroads carrying heavy high speed traffic to determine if the bolts would stay tight under operating conditions. The bolts were placed in both the connections of new bridges and in the connections of older bridges where the rivets were continuously working loose under traffic. Over 700 bolts have been installed in eleven different structures.

The field tests of the high-strength bolts have not been underway long enough to afford conclusive results, but the data that are available indicate that the bolts are proving to be satisfactory and there is no indication of the nuts turning.

Project V—K. H. Lenzen, Chairman

The effect of grip upon the fatigue strength of riveted and bolted joints.

The Technological Institute—Northwestern University.

The purpose of this project is to determine the effect of grip on the fatigue strength of riveted and bolted structural joints. It is hoped that the effect of clamping force and the degree of filling of holes on the fatigue strength of joints can be determined for various types of fasteners. In addition, a direct comparison may be obtained as to relative fatigue strength of structural joints fabricated with various fasteners. This project will consider hot-driven rivets, cold-driven rivets, and bolts. If any alloy rivets are considered worthy of testing, they are to be included in the project.

Much work has been previously done as to the fatigue strength of joints fabricated with hot-driven rivets. Tests have been made by several investigators in which it was shown that the clamping force of a rivet varies with length of grip. The effect of grip on the fatigue strength of joints fabricated with hot-driven rivets was partially studied by Professor Wilson and reported in Bulletin 302 of the Engineering Experiment Station of the University of Illinois. No comparative studies, however, have been made of joints fabricated with cold-driven rivets and bolts. In certain cases cold-driving has recently become an acceptable practice in shop fabrication. In addition, the possibility of accepting bolted connections for conditions of fatigue loading has been suggested by many engineers.

The first series of specimens considered in this project are double-butt joints having a tension: shear: bearing ratio of 1.00:0.75:1.56. Four types of fasteners are considered; namely, hot-driven rivets, hot-formed and cold-formed cold-driven rivets, and bolts. The diameter of each fastener is ¾ in. The joints are fabricated with two rows of three fasteners in each row. It is expected that differences in fatigue strength will be due to variations in distribution of load within the joint caused by differences in clamping force and filling of holes for the various fasteners. Three values of grip are considered for the various fasteners and are $1\frac{5}{16}$ in., $2\frac{1}{16}$ in., and $3\frac{1}{16}$ in.

This series of tests includes 108 specimens having a total weight of 14,400 lb. Nine specimens will be tested for each fastener at a particular grip and will include static tests and fatigue tests from zero to tension and complete reversal of stress.

All of the specimens have been received by Northwestern University and the testing has started.

Project VI—J. L. Beckel, Chairman

The fatigue strength of high strength steel riveted joints.

The Technological Institute—Northwestern University.

It is the purpose of this project to determine the fatigue strength of high strength alloy steels suitable for structural work, particularly in those structures such as bridges

reversed load, depends upon many factors, and a large number of carefully planned tests will be necessary. It is believed, however, that the possibilities of a high-strength bolted joint to resist fatigue, and the consequent economic advantages, warrant the large number of tests planned to evaluate these factors and establish reliable design data.

TABLE 1.—SOME RESULTS OF FATIGUE TESTS ON BOLTED JOINTS

Description of Specimen	*Initial Bolt Tension, Lb. Per Bolt*	*Stress Cycle, psi Unit Shear on Body of Bolt**	*Number of Cycles*
Four 1-in. bolts in a square pattern	45, 500	0 to ±15, 300	2, 829, 100. Had no appreciable effect on joint
Four 1-in. bolts in a square pattern 4-in. grip	16, 000	0 to ±13, 790	2, 502, 400. Had no appreciable effect on joint
Four 1-in. bolts in a square pattern 4-in. grip	45, 500	−20, 450 to +20, 450	4, 208, 900. Slight slip at beginning of test that decreased as test continued
Three 1-in. bolts in a triangular pattern 4-in. grip	65, 000	−27, 000 to +27, 000	3, 654, 200. Slight slip that did not vary appreciably during test

* This is referred to as shear on the bolt, but as a matter of fact, the shear on the joint is resisted by friction between the plates.

The bolted specimens described above consisted of a center plate and two side plates joined by 1-in. high-strength bolts. Various details of the assembly follow:

1. Bolts were American Standard Regular heads with finished bearing surface under the head to get good seating and had a fillet joining the head and shank. The bolts were of carbon steel, quenched and tempered, and had a minimum yield point of 85,000 psi.
2. Nuts used were American Standard Heavy, Semifinished. It is possible that narrower Regular nuts may be satisfactory, but Heavy nuts were used to insure against abrasion of the bearing surface under the high torque loading.
3. Hardened washers, carburized 0.015 in. minimum, were used under the bolt head and nut to insure maintenance of high clamping force.
4. No locking devices were used to prevent nut loosening, as it was believed that they would be unnecessary if high clamping force were maintained. This was borne out in laboratory tests running several million reversals of load without evidence of loosening.
5. Experiments indicated that the torque required to induce the necessary clamping force can be estimated as 0.2 in.-lb. per inch bolt diameter per pound of bolt load. Bolt tensions of 1-in. bolts in these studies were as high as 50,000 lb. per bolt (82,500 psi.).

Preliminary laboratory studies have been conducted at Northwestern Technological Institute and were sponsored by the Industrial Fasteners Institute. These studies consisted of obtaining a comparison of the behavior of structural joints fabricated with various fasteners. Joints fabricated with hot-driven rivets, cold driven rivets and high-strength bolts were subjected to various cylces of fatigue loading. The results of these tests are reported in Bulletin 481, June–July 1949, of the American Railway Engineering Association.

of the project will be in a position to materialize, and further testing of the acceptable low alloy high strength steels in riveted and bolted joints will be warranted.

It is expected that the specimens will be received at the laboratory so that the actual testing in the first phase of this project can be started within the next few months.

Project VII—L. E. Philbrook, Chairman

Effect of rivet pattern on the fatigue strength of structural joints.

The Technological Institute—Northwestern University.

Fatigue failure of riveted structural members is not a newly discovered phenomenon, but little is known about it. There is a dearth of experimental data on the effect of variation of rivet pattern on fatigue strength of structural joints. A notable exception is the work of Professor Wilson, who reported in 1938 the results of a limited number of tests in Bulletin 302 of the Engineering Experiment Station of the University of Illinois.

As a result of increased traffic and heavier loading on old bridges during the war, fatigue cracks were found to be developing in some structures. Fatigue is now recognized by many designers as a reality to be considered in the design of members subject to numerous applications of live load. It is the purpose of this project to furnish data on which the design of joints for these members can be based.

The immediate agenda of this project has been divided into three parts:

1. To investigate the possibility of successive failure of rivets in a long joint. This is premised on the assumption that, in a long joint, an applied load is not distributed equally among all rivets in the joint. Unequal participation may lead to successive failure of the rivets.

   This group includes two types of specimens, (a) butt joints consisting of plates with 8 rivets in a single line, and (b) lap joints consisting of one channel section and one plate with two lines of 7 rivets, a total of 14 rivets. All rivets are ⅞-in. and hot-driven. Seven specimens of each type have been received at the Technological Institute of Northwestern University. The total weight of material required for the 14 specimens is 4000 lb.

2. To explore the effect of staggering the rivets in the end row of a rivet pattern otherwise maintaining constant the pitch and transverse spacing of rivets in the group. The rivet pattern will consist of several rows of four rivets each. In one series of specimens the pitch and transverse spacing of rivets will be identical. In the remaining series, the pattern is to be the same except for staggering of the end rivets. Staggering of rivets will be obtained in one series by increasing the pitch of the end rivet in each of the longitudinal rows; and, in the other series by similarly increasing the pitch of the end rivet in each of the inside longitudinal rows.

   This group includes butt joints having several rivet patterns and seven specimens of each pattern. Additional blank plates are proposed from which extra specimens can be fabricated if required.

3. To explore the effect of varying the pitch and transverse spacing of rivets in the pattern.

   This group will include 4 rivet patterns, with 7 specimens for each pattern making a total of 28 specimens. Additional blank plates are again proposed for contingencies. In these specimens, the rivet pattern also will consist of several rows of four rivets each. The variables of these specimens are to be the pitch and transverse spacing.

in which the members are subject to fatigue stresses. This will naturally include the investigation of these high strength steels in relation to fatigue when they are joined by rivets or bolts.

The scope of the project is rather broad in that the preliminary stages will embrace the investigating of various high strength alloy steels which are now commercially rolled to determine which of these steels performs satisfactorily in fatigue with the intent, after these preliminary studies are made, to subject the various acceptable alloy steels to further testing in riveted and bolted joints. Much of the ground work in regard to rivet patterns, etc. will be covered by several of the other projects and it is the intent that by the time Project No. 6 is ready for the testing of these steels in riveted and bolted joints, the question of rivet patterns, etc. will be fairly well defined. It will then be in the province of Project No. 6 to accept the data which has been determined by the other projects and apply it to the fatigue testing of joints made with high strength alloy steels.

The first phase of Project No. 6 will be the testing of commercial alloy steels supplied by the various manufacturers listed below:

Mayari–R (Bethlehem)
R. D. S. (Republic)
Yoloy (Youngstown)
HI-Steel (Inland)
Cor-ten (Carnegie–Illinois)
Mn-Ni-Cu (Carnegie–Illinois)
Otiscoloy (Jones & Laughlin)
A7 (Carnegie–Illinois)
A7 (Bethlehem)
A94 (Carnegie–Illinois)
A94 (Bethlehem)
3½ Nickel Grade E (Lukens)

The two specimens of A7 carbon steel included in this list are for comparative purposes.

The static tension and fatigue tests will be made on specimens ⅝ in. by 4 in. with a hole in the center, drilled by the laboratory to 1 1/16 in. diameter. The edges of the plates are to be flame-cut and then machined to a depth of ¼ in.

Two fatigue specimens will be tested of each of the above steels in a cycle from 0 to 27,000 psi. in. tension. Two additional specimens will be furnished and kept as spares in the event any additional testing is required for that particular steel. It is also the intention to have these specimens furnished without holes, the holes to be put in the specimens by the laboratory. It will, therefore, be possible to use the two additional spare specimens for testing without a stress-raising hole, if it is so desired.

Two tension specimens, similar in cross section to the fatigue specimen, will be tested in static tension to determine the average tensile strength of the various steels. Coupon specimens will be cut to 1½ in. by ⅝ in. and tested in static tension.

It is intended to test only the A94 silicon steel specimens under two conditions of workmanship. One will be a flame-cut specimen with machined edges in accordance with the present AREA specification and the other will be a machine flame-cut post-heated specimen.

This preliminary testing of the fatigue specimens with the stress raising hole should establish the acceptability of one or more of the low alloy high strength steels insofar as their fatigue strength is concerned. When these tests are completed, the second phase

Report of Committee 16—Economics of Railway Location and Operation

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W. H. Wood
J. S. Worley

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

AREA Bulletin 483, November 1949.

Five specimens of the butt type of joint of the first group, designed to investigate the progressive failure of rivets, have so far been tested. In all cases failure occurred in the plates. The results of these tests are recorded in Table 2.

TABLE 2.—TESTS OF BUTT JOINTS

Stress (psi)	Cycles at Failure	Indicated Fatigue Strength at 2,000,000 Cycles (psi)	Slippage Top (In.)	Middle (In)	Bottom (In.)
—16, 000 to +16, 000 (net area)	917, 762	± 14, 700	0.0025	0.00050	0.0035
—16, 000 to +16, 000 (net area)	1, 050, 205	± 15, 000	0.0020	0.00050	0.0025
0 to +24, 000 (net area)	700, 549	0 to +21, 600	0.0010	0.00025	0.0020
0 to +24, 000 (net area)	1, 960, 000	0 to +24, 000	0.0015	0.00050	0.0035
0 to —21, 500 (gross area)	*		0.0010	0.0	0.0020

* No failure after 2,200,000 cycles. Range of load was changed to produce a stress cycle of 0 to — 25,000 psi. with no failure after 3,000,000 cycles but with slippage values of 0.002, 0.0 and 0.003 in.

Details were prepared for specimens of the lap type of joint for the second and third parts of the proposed agenda. These specimens have not been fabricated because difficulties were encountered in the laboratory in testing other lap-joint specimens. This difficulty arises because flexure is induced in the specimens when placed in the testing machine, due to the eccentricity inherent in this type of specimen. These problems are now being studied but a decision has not been reached as to the procedure to be followed in testing laptype specimens.

In the above project reports, it can be seen that substantial progress has been made in (1) determining the projects which would advance necessary knowledge for the design of structural joints, (2) determining the detailed procedure of the projects, (3) acquiring the specimens for testing and (4) the actual laboratory testing.

From time to time, additional reports will be issued of the findings of the finished projects and the status of those in progress.

Page 16–5, subparagraph (1) *Frictional Resistance.*

Delete the words "with modern equipment" in second line

Insert the words "with modern friction bearing equipment."

Page 16–5, below the last paragraph under (1) *Frictional Resistance.*

Insert another paragraph reading:

For greater refinement and higher speeds, use of the Davis formula on page 16–37 is recommended.

Page 16–9, second paragraph.

Delete third, fourth and fifth lines.

Insert: If steam locomotives burning coal are the motivepower used, since a steam locomotive burns considerably more coal per horsepower at low than at high speeds, it should be understood that this method will not indicate the full disadvantage of heavy adverse grades where low speeds prevail.

Page 16–9, third paragraph.

Delete the word "coal" in second line.

Insert the word "fuel."

Page 16–45, first paragraph.

Delete from third, fourth and fifth lines the sentence beginning with the word "Generally" and ending with the word "traffic."

Page 16–45, ninth line.

Delete entire line.

Insert: Ways in which operation can be bettered, namely:

Page 16–45, fourteenth line.

Delete the word "coal."

Insert the word "fuel."

Page 16–46, lines 13 and 14.

Delete the word "coal" from both lines.

Insert the word "fuel" in both lines.

Page 16–46, line 16.

Delete the sentence inside of parenthesis.

Insert: (Water for (15) and (16) to be figured on the basis of one gallon of water per pound of coal or equivalent).

Page 16–46, line 25.

Delete entire wording.

Insert: Car repair expense per freight car mile.

Insert under line 25 the following new line:

26. Car repair expense per passenger car mile.

Page 16–46, paragraph under 2—Interest.

Delete entire paragraph and insert:

Interest should be computed at current rates, variable with different railroads. There will be no charge for this item under present operation.

Page 16–48, first paragraph at top of page.

Delete the words "seven pounds" in second line.

Insert the words "one gallon."

Page 16–48, sixth paragraph from top of page.

Delete entire paragraph and insert:

Depreciation.—Charge to both present and proposed operations where applicable.

7. Yards, effect of their location on the economics of railway location and operation, collaborating with Committee 14.

THE COMMITTEE ON ECONOMICS OF RAILWAY LOCATION AND OPERATION,
C. H. BLACKMAN, *Chairman.*

Report on Assignment 1

Revision of Manual

E. G. Allen (chairman, subcommittee), E. E. Kimball (vice-chairman, subcommittee), H. A. Aalberg, B. T. Anderson, J. W. Barriger, F. C. Berghaus, C. H. Blackman, I. C. Brewer, Miss Olive W. Dennis, J. T. Fitzgerald, J. M. Fox, H. C. Hutson, W. B. Irwin, W. M. Jaekle, H. A. Lind, R. L. Milner, F. N. Nye, F. B. Peter, W. E. Quinn, J. P. Ray, W. T. Rice, R. W. Rogers, A. L. Sams, J. A. Schoch, K. W. Schoeneberg, L. K. Sillcox, R. F. Spars, A. E. Street, J. E. Teal, D. K. van Ingen, H. D. Walker, F. G. Walter, H. L. Woldridge, W. H. Wood.

Your committee makes the following recommendations for revision of the Manual:

Page 16–1, last paragraph, fourth line.

Delete: Care should be taken not to use too low a rate of interest.

Insert: Interest should be computed at current rates, variable with different railroads.

Page 16–2, paragraph 2—Locomotive Districts, subparagraph (a).

Delete and insert:

(a) *Length of District.*—The locomotive district should be of sufficient length to enable freight trains powered by modern locomotives to move a maximum distance at permissible speed within the hours of service of the crew, allowing reasonable leeway for reduced mileage within the hours of service as a result of delays or unfavorable weather conditions.

Page 16–4, fifth line under subheading (c) *Curvature:*

Insert the word "increasing" before the words "line resistance" so that the fifth line will then read "curvature increasing line resistance in one direction only."

Page 16–4, subparagraph numbers under (d) *Curve Resistance—Freight Cars.*

Delete: (1′), (2′), (3′), and (4′)

Insert: (1), (2) (3) and (4).

Page 16–4, subparagraph (2) under (d) *Curve Resistance—Freight Cars.*

Delete entire wording and insert:

(2) The cause of this pressure is the tendency of a cylindrical body to rotate in a plane at right angles to the axis of rotation.

Page 16–4, subparagraph (3) under (d) *Curve Resistance—Freight Cars.*

Delete the words "slightly retardation" in third line.

Insert the words "slight retardation."

Page 16–5, subparagraph numbers under (e) *Line Resistance.*

Delete: (1′), (2′), (3′) and (4′)

Insert: (1), (2), (3), and (4).

THE COST OF STOPPING AND STARTING STEAM OPERATED TRAINS

1950

For detailed discussion, tables, charts and examples, see the following:
AREA Proceedings, Vol. 28, 1927, pp. 473, 1319.
AREA Proceedings, Vol. 37, 1936, pp. 541, 974.
AAR Signal Section, 1946 Proceedings, Vol. XLIV, pp. 7A–12A.

Pages 16–75 and 16–76

Formula for Determining Comparative Economies of Flat and Hump Yard Switching

1936

Delete above heading and entire section
Insert following temporary heading and references:

FORMULA FOR DETERMINING COMPARATIVE ECONOMIES OF FLAT AND HUMP YARD SWITCHING

1950

For reports on this subject see the following AREA Proceedings:

Vol. 31, 1930, p. 1014.
Vol. 32, 1931, pp. 693, 832.
Vol. 37, 1936, pp. 536, 974.

Report on Assignment 3

Methods and Formulas for the Solution of Special Problems Relating to Economics of Railway Operation

B. T. Anderson (chairman, subcommittee), I. C. Brewer, D. E. Brunn, H. S. Bull, W. T. Elmes, C. H. Fox, E. T. Hammer, J. M. MacBride, W. E. Quinn, W. T. Rice, H. C. Rowe, B. J. Schwendt, H. M. Shepard, D. K. van Ingen, F. G. Walter, H. P. Weidman, H. L. Woldridge.

Your committee submits the following progress report as information.

The Renaissance of the Chicago, Indianapolis & Louisville Railway

While this report applies to the "Monon," Committee 16 does not wish to convey the impression that other railroads with similar conditions have not improved their financial condition by means of large improvement programs.

The Monon story is different from other railroads in that it applied to a Class I Railroad capitalized at 30 million dollars on which the entire railroad plant including locomotives, freight, passenger and work equipment, track, bridges, structures, signals, etc., were in an obsolete condition. Strenuous measures were necessary if the railroad was to survive the reorganization in a period of high operating and material costs in the postwar years.

Since the reorganization on May 1, 1946, approximately 17 million dollars have been spent for Road and Equipment and 3 million dollars for Operating Expenses, a total of 20 million dollars, for new motivepower, equipment, roadway, etc., and further large expenditures will be required to complete the program on the entire railroad.

Page 16–48, under 6. Maintenance of Way and Structures.

Delete the following subparagraph headings:

Insert: *Structures.*—Steel Bridges
Creosoted Wood Bridges
Signals
Structures.—Steel Bridges*
*Creosoted Wood Bridges**
*Signals**

Insert under subparagraph following the new heading *Signals* the following new heading and subparagraph:

Depreciation.—Charge to both present and proposed operations where applicable.

Insert under new subparagraph following the new heading *"Depreciation"* the following new footnote:

Page 16–49, item 2 under Annual Cost.

Delete the words "Interest on net cost, 5 percent."

Insert the words "Interest on A & B."

Page 16–49, under 6. Maintenance of Way and Structures.

Insert under (d) Signals the following additional line:

(e) Depreciation where applicable.

Page 16–51, paragraph 4.

Delete entire paragraph and insert:

4. Summits and sags within tunnels should be avoided, if possible, in the interest of efficient ventilation.

Page 16–71

Operation of Trains Against Current of Traffic on Multiple Tracks

1925

Delete above heading and the paragraph at bottom of page and insert the following:

OPERATION OF OPPOSING AND FOLLOWING MOVEMENT OF TRAINS BY BLOCK SIGNALS ON MULTIPLE TRACKS

1950

Where the volume and distribution of traffic on a multiple track line are such as to cause delays to trains sufficiently serious to warrant the consideration of means of effecting relief, the operation of opposing and following movement of trains by block signals is recommended for improving train operation and as affording a means of increasing capacity at a small expenditure comparable with the cost of additional facilities sufficient to give relief. Railroads operating in this manner must provide proper signals to control the approach and movement of trains.

Pages 16–72 to 16–75

The Cost of Stopping and Starting Trains

1936

Delete above heading and entire section.

Insert following new heading and references:

* Use cost units related to the year 1914 as the base period for the purpose of trending ICC indices

The revenue freight and passenger train miles and locomotives and cars owned from 1943 to 1948 are shown in Table 1.

The gross revenue in recent years is shown in Table 2.

Some of the operating improvements made in 1948 and 1949 as compared to previous years are shown in Table 3.

TABLE 3

Item	*Year* *1946*	*1947*	*1948*	*6 Mo's 1949*	*Percent Ratio 49/46*
Net income	*$1,262,996	$105,325	$718,185		
Total car loadings	169,429	196,697	208,197	96,127	123†
GTM per train hour	28,761	29,528	34,230	37,652	131
Gross tons per train	1,803	1,681	1,965	2,106	117
Operating ratio	89.6	82.2	81.3	85.8	95.8
Car miles per car day	39.0	52.1	52.3	54.7	140
Frt. train miles per train hour	17.1	17.7	17.5	17.9	105

* Deficit in 1946.
† Ratio 1948/1946.

Progress of Modernization Program

Motive Power Program

Since the Monon was reorganized on May 1, 1946, it has been completely dieselized, the last steam locomotive in road service being retired in June 1949. The Monon is the largest Class I railroad with completely dieselized operation.

Thirty-six diesel locomotives, 52 units with 74,000 hp. were in service on January 1, 1949 and cost $6,788,603. Five additional diesel locomotives, (three 1500-hp. road switchers were delivered in May 1949 and two 600-hp. switchers scheduled for delivery in August 1949), will be placed in service in 1949. These 41 diesel locomotives take the place of 76 locomotives (72 steam locomotives and 4 diesel switch engines) owned on May 1, 1946. The 37 diesels replaced 72 steam locomotives or a ratio of 1 to 1.95. This ratio compares to 1.44 for the year ending April 1, 1948, for the entire country, and 1.06 for the year ending April 1, 1949.

The new diesel maintenance shop† at Lafayette was placed in service in March 1948 and since that time all diesel locomotive maintenance has been concentrated in this new shop, with the exception of daily inspection of the road locomotives and monthly inspection of switching locomotives, which are performed at the three small outside maintenance terminals located at South Hammond, Indianapolis, and McDoel, Ind.

When the roundhouse at Lafayette was torn down all the steam locomotive service and repairs were moved to the southern end of the railroad and the remaining steam locomotives were taken care of in the roundhouse at McDoel. All the water treating, pumping stations and coal docks north of McDoel were retired during 1948 and all remaining steam facilities will be retired in 1949. The five-stall roundhouse at Midland, Ind., in the coal fields, was abandoned early in 1948. The five-stall roundhouse at Michigan City, Ind., was abandoned and torn down about the same time. Nine of the 14 stalls in the roundhouse at Belt Jct. were abandoned. The steam power plant in this

† Railway Age, June 12, 1948, pp. 54–57.

The first report* on the Monon outlined the proposed improvement program for the years 1947, 1948 and 1949, and included details of operating data from 1936 to 1946. It is proposed in this year's report, to include similar data for the years 1947, 1948 and part of 1949 and report on some details, including economics of the motivepower, equipment, roadway, signal, and communications improvements already in service and under way.

The Monon improvement program which has been partially completed as of July 1, 1949, includes:

Complete dieselization of the railway
New diesel maintenance shop at Lafayette
New passenger and freight cars
Retirement of 67 old steam locomotives
Retirement of facilities incidental to operation of steam power
Improvement in freight and passenger schedules
New and heavier track structure and line change
New interlockings at former nonprotected railroad grade crossings.

The original plan for an estimated expenditure of 26 million dollars during 1947, 1948 and 1949, has been modified to suit the increased operating costs during the post-war years. This has resulted in slowing up the improvement program and extending the period for completion of some of the contemplated plans.

The modernization program already completed has resulted in reduced operation expenses in spite of the increase in operating expenses incidental to the retirements for obsolete motivepower, abandoned roundhouses, water service facilities, etc. Without these improvements and increased traffic it is doubtfull if the Monon could have remained in operation at the present day level of prices and rates.

TABLE 1

	Revenue Train Miles		Equipment Owned	
Year	*Freight*	*Passenger*	*Locomotives*	*Freight and Company Cars*
1943	1,040,518	777,698	89	3802
1944	992,306	780,935	89	3616
1945	899,842	460,188	88	3241
1946	1,072,838	499,354	76	1854
1947	1,364,165	806,493	63	2457
1948	1,226,865	805,247	59	2900
1949 (6 Mo's)	531,040	381,890	57	2903

TABLE 2

Year	*Gross Revenue*
Average 1937–1946	$10,845,000
Peak year 1944	13,490,000
1945	11,556,500
1946	11,457,996
1947	15,586,376
1948	19,055,141
1949 (6 Months)	8,808,793

* Proceedings, Vol. 49, 1948, pp. 14, 564.

SAVING IN DIESEL OPERATION OVER STEAM 1948 VERSUS 1946

Decreased Annual Operating Expenses:	
Estimated saving due to:	
Freight train operation	$ 226,970
Passenger train operation	56,367
Yard operations	30,506
Reduction in freight train miles	237,403
Maintenance on retired steam facilities, 5 percent	47,174
Depreciation on retired steam facilities 2.06 percent	19,435
Reduction in taxes, 3.46 percent of 1/3 of $943,472	10,881
Depreciation on retired steam locomotives 3.88 percent of $2,790,120	108,256
Reduction in taxes on retired steam locomotives 3.46 percent of 1/3 of $2,790,120	32,179
Total decreased annual operating expenses	$ 769,171
Increased Annual Operating Expenses:	
Interest on diesel locomotives, 2 percent of $6,788,603	$ 135,772
Maintenance on new diesel facilities	8,849
Depreciation on new diesel facilities	7,292
Taxes on new diesel facilities	4,082
Depreciation on new diesel locomotives	263,398
Taxes on new diesel locomotives	78,295
Total increased annual operating expenses	$ 497,688

ECONOMIC STATEMENT

Gross saving per year	$ 769,171
Increased annual operating expenses	497,688
Net saving per year before income tax	$ 271,483
Income tax saving in 1948	
38 percent of net retirements of $3,255,068	$1,236,926
Less net saving on operations, 38 percent of $271,483	103,164
*Net saving on income tax	$1,133,762
Total Income Tax and Operating Saving in 1948	
Net income tax saving	$1,133,762
Net operating saving	271,483
Total saving in 1948	$1,405,245

Annual Return Over Interest, Taxes and Depreciation:

(a) On Total R&E of $3,887,497

$$\frac{1,405,245}{3,887,497} \text{ equals 36.1 percent}$$

(b) On Total Cost of $7,142,565

$$\frac{1,405,245}{7,142,565} \text{ equals 19.7 percent}$$

Equipment Program

The 28 new passenger cars converted from army hospital cars were rebuilt in the Lafayette shops and placed in service in 1948. During the first nine months of 1948 the

* This income tax saving is non-recurring as the amount will vary from year to year depending on the savings made by the improvements, the amount charged to operating expenses for retirements, and the income of the railway.

roundhouse has been replaced with automatic oil-fired steam generators which eliminated three-trick attendance.

An automatic steam generator has been installed at Lafayette and at McDoel which permitted shutting down the large steam plants at these points during the summer months. Automatic electric air compressors are now used at all terminals to supply air to shops and train yards. All of these improvements have resulted in reducing the annual operating expense to the railway.

Both freight and passenger schedules have been improved with the modernization program already in service. Reductions in time, as examples, are as follows:

	Freight Trains		*Passenger Trains*	
	Formerly	*Now*	*Formerly*	*Now*
Between	*hours–min.*	*hours–min.*	*hours–min.*	*hours–min.*
Chicago–Louisville	12–45	9–45	9–5	7–45
Chicago–Indianapolis	8–45	7–45	4–15	3–50

Based on 6 freight trains daily in 1948 between Chicago and Louisville and 4 between Chicago and Indianapolis, the total freight train hours saved per year amounts to 8030 hours.

Based on 4 passenger trains daily between Chicago and Louisville and 4 between Chicago and Indianapolis, the total treight train hours saved per year amounts to 2555 hours.

The expedited freight and passenger operation is estimated to reduce the annual operating expenses as follows:

Expedited freight trains	$178,900
Expedited passenger trains	25,500
Car day saving	38,099
Total	$242,499

Due to increased tonnage rating of the 4500 hp. diesel locomotives, 3200 vs. 2150 tons compared to the Mikado steam locomotives operated on the southern division between Louisville and McDoel, an estimated 100,297 freight train miles were saved in 1948 as compared to 1946.

These improved schedules and increased traffic solicitations have resulted in increased freight and passenger revenue in 1948 over the previous years.

A comparison has been made of the diesel operations for 1948 as compared with steam operation in 1946. During 1946 all road locomotives were operated with steam power except that late in December 1946 eight road diesel units were placed in service. During 1948 approximately 94 per cent of road locomotives were diesel operated.

Allowing for increases in wages and the cost of material and fuel in 1948 over the figures for these items in 1946, the estimated saving in diesel over steam operation, is as follows:

GROSS EXPENDITURE FOR NEW DIESELS AND FACILITIES

Item	*R&E*	*O.E.*	*Total*
36 diesel locomotives	$6,788,603		$6,788,603
New diesel facilities	353,962		353,962
Retirement of 67 steam locomotives, less salvage, net credit ($2,790,120–$440,785)	2,349,335	$2,349,335	
Retirement of steam facilities, less salvage net credit ($943,472–$37,739)	905,733	905,733	
Total	$3,887,497	$3,255,068	$7,142,565

5. *New Siding at Lafayette Jct., Ind.*—A new 6200-ft. 130-car siding has been installed at Lafayette Jct., 1.5 miles south of Lafayette, which has been of operating benefit in making meets and passes adjacent to the 10-mph. territory through the streets of Lafayette.

Signal Program

Three interlockings have been installed, of the eight proposed in the 1947–1949 budget, and two others are under discussion with the interested railroads in July 1949.

Some of the important details of the three interlockings which involved single-track crossings on both railroads, are as follows:

No.	*Location*	*Other RR Involved*	*Type*	*Average Trains Daily*	*In Service*
1	Gosport Jct. ..	P. R. R.	Automatic	10	1947
2	Roachdale	B. & O.	Attended	10	1948
3	Linden	N. Y. C. & St. L.	Attended	12	1948

No.	*Freight Train Hours Saved Yearly*	*Total Train Stops Saved Yearly*	*C.I.&L. R&E Cost*	*Estimated Annual Saving*	*Percent Return on R&E*
1	300	3600	$16,500	$8,277	50.2
2	300	3600	24,000	7,527	31.4
3	426	4344	24,000	11,266	46.9

The estimated annual saving is the net saving per year over maintenance and operation, interest and depreciation and based on 1949 traffic.

In July 1949, plans were under way for consolidating two interlockings at Maynard, Ind. The present Grand Trunk–Monon crossing interlocking will be controlled from the Pennsylvania–Grand Trunk crossing interlocking, about 2200 ft. away, with estimated savings of about 20 percent to the Monon.

At the time of the Cedar Lake line change, the existing semaphore automatic block signals between St. John and Lowell, 11.3 miles, were respaced and replaced with searchlight type, three-indication, color-light signals. Six semaphore automatic block signals were retired, two new searchlight signals were added, and eight semaphore signals were changed to searchlight type with reduced operating expenses.

Highway grade crossing protection is now being installed at Bloomington and Michigan City, Ind. on four crossings in each city, with estimated saving of about 30 percent at each city.

Communication Program

One additional carrier circuit has been installed between Chicago and Lafayette to provide increased telephone facilities between those points. The Western Union pole line has been taken over by the Monon on the entire railway.

Mechanized Accounting

Mechanized accounting was installed at Chicago in May 1948. Rapid progress is being made in changing over from clerical to mechanized accounting for all accounting work on the railway.

entire car forces at Lafayette were used in rebuilding the hospital cars. All labor and material for this work was charged to R&E and did not appear in operating expenses.

From October 10 to December 31, 1948, 122 low-side gondola stone cars were restored to service at an average cost of $450 per car or a total cost of $54,900, the charges being made to operating expenses.

From January 2, 1949 to June 15, 1949, 72 hopper cars were restored to service at a cost of $1220 per car or a total of $87,840, the charges being made to operating expenses.

The 194 cars were restored to service at a total operating cost of $142,740. Had these cars been scrapped and 194 new cars purchased, it would have required an expenditure of approximately $5000 per car or a total of $970,000.

During this same period, 97 heavy bad order freight cars were repaired and restored to service, the charges being made to operating expenses.

Roadway Program

While the contemplated nine million dollar 1947–1949 budget program has been modified, the roadway improvements since 1947 include the following:

1. *Line change at Cedar Lake, Ind.*—This change in line installed in 1948 involved 3.8 miles of single track, 0.03 longer line, on a new right-of-way and saved renewing a wood trestle over which trains were restricted to 20 mph. The maximum grade was reduced from 0.48 percent to 0.24 percent and maximum curvature from 3 to 1 deg. with four less curves. The new line included 112-lb. rail and rock ballast designed for authorized speed of 75 mph. for passenger trains and 55 mph. for freight trains. The approximate cost was:

R&E	*O.E.*	*Total*	*Salvage*
$372,062	$14,486	$386,548	$32,519

While an economic study has not been made of this improvement, it has helped to increase the operating efficiency of the railway.

2. *Wabash river bridge, Delphi, Ind.*—The old through-truss Wabash river bridge at Delphi on which there is a speed restriction of 10 mph. was replaced during the summer of 1949 with a new deck plate girder bridge on an improved grade. The 7 through-truss spans and 2 deck girder spans are being replaced with two 100-ft. and thirteen 75-ft. deck plate girder spans requiring 7 new concrete piers at an approximate cost of $300,000.

3. *Rail Program.*—The miles of rail installed per year since 1946 have been as follows:

Year	*Miles New 112-lb.*	*Miles New 115-lb.*	*Miles Relay 90-lb.*	*Miles Relay 112-lb.*
1946	12.24			
1947	9.61			
1948	24.08	3.68		
1949		9.35	9.98	0.5

4. *Cross tie program.*—The new cross ties used in replacement per year have been as follows:

Year	*Number*
1946	52,840
1947	90,704
1948	122,989
1949	104,262

In 1948, 169 ties were replaced per mile of track compared to 124 in 1947. The five-year average per mile of track in 1948 was 96.

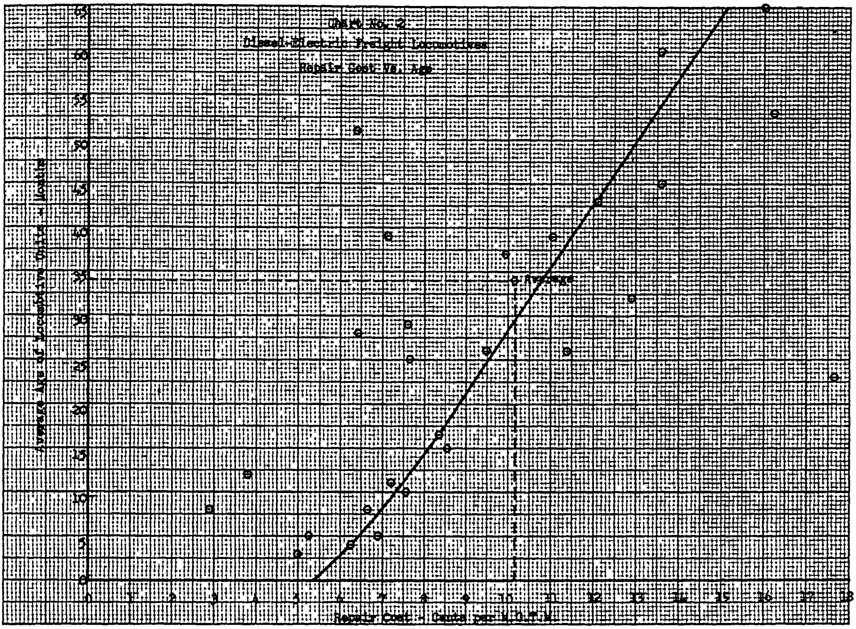
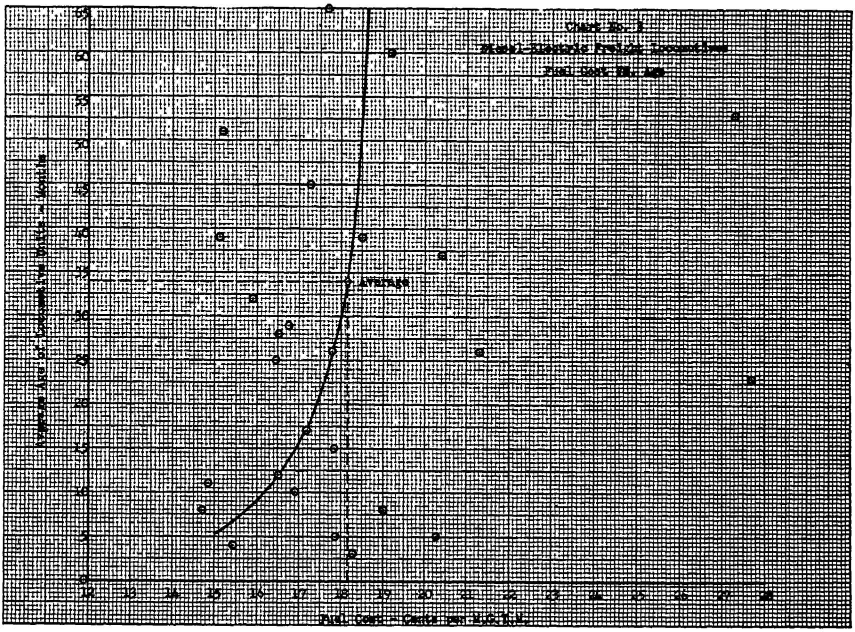


Chart No. 2
Diesel-Electric Freight Locomotives
Repair Cost Vs. Age
Average


Average

Conclusion

While the progress already made has been less than expected, the accomplishments to date have resulted in improved service, faster schedules, increased revenue and decreased cost of operation. The committee intends to follow the Monon improvements and report in succeeding years on the economic results of their program.

Report on Assignment 5

Electrification and the Development of Modern Power Units

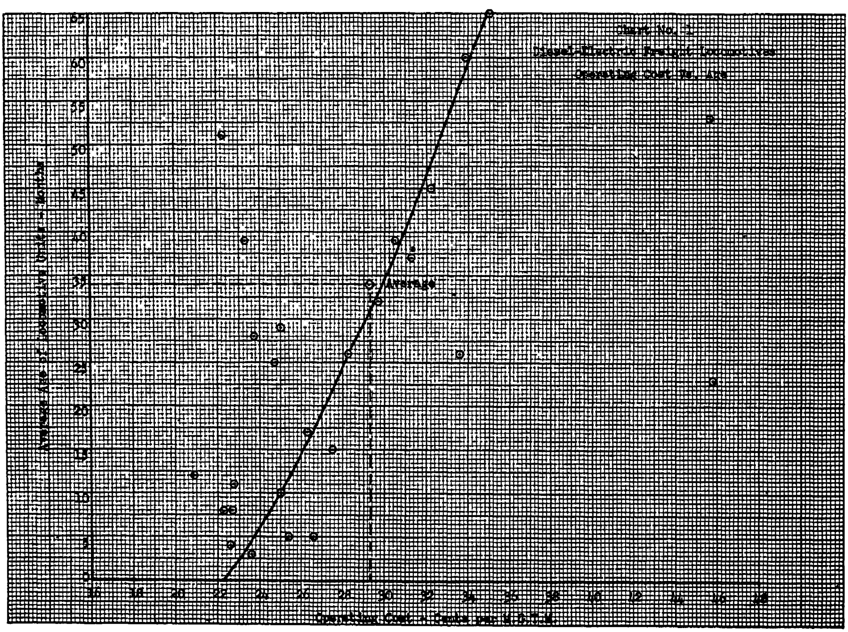
Collaborating with the Electrical Section, Engineering Division, and Mechanical Division, AAR

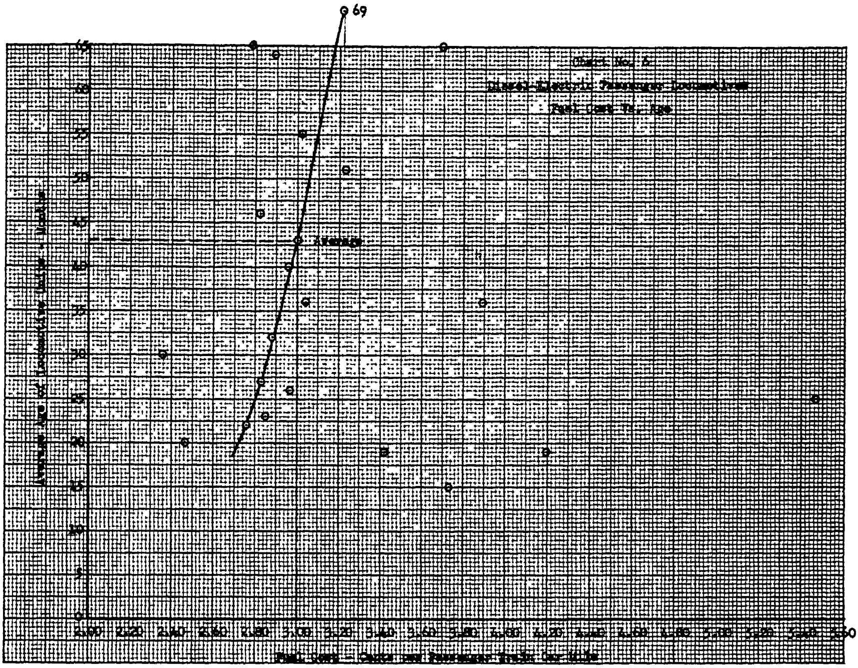
L. K. Sillcox (chairman, subcommittee), E. G. Allen, J. W. Barriger, C. H. Blackman, H. S. Bull, Miss Olive W. Dennis, W. T. Elmes, W. B. Irwin, E. E. Kimball, F. H. McGuigan, Jr., F. N. Nye, W. T. Rice, R. W. Rogers. E. H. Roth, J. A. Schoch, H. F. Schryver, H. M. Shepard, H. D. Walker.

This report is presented as information, with the recommendation that further study be deferred until such time as more experience data have been accumulated or authentic performance data of present exploratory motive power designs have been established.

Accompanying this discussion are a series of three tables and a set of nine graph sheets predicated upon the data herewith submitted. These data relate to pertinent operating indicators and costs of diesel-lectric locomotives assigned to freight, passenger, and yard services and it is the belief of your committee that sufficient material has been obtained to be indicative of the characteristics displayed by diesel-electric power. Data applicable to 27 groups of freight locomotives, 23 groups of passenger locomotives, and

(text continued on page 111)




69
Chart No. 6
Diesel-Electric Passenger Locomotives
Fuel Cost Vs. Age
Average
Average Age of Locomotive Units - Months
Fuel Cost - Cents per Passenger Train Car Mile

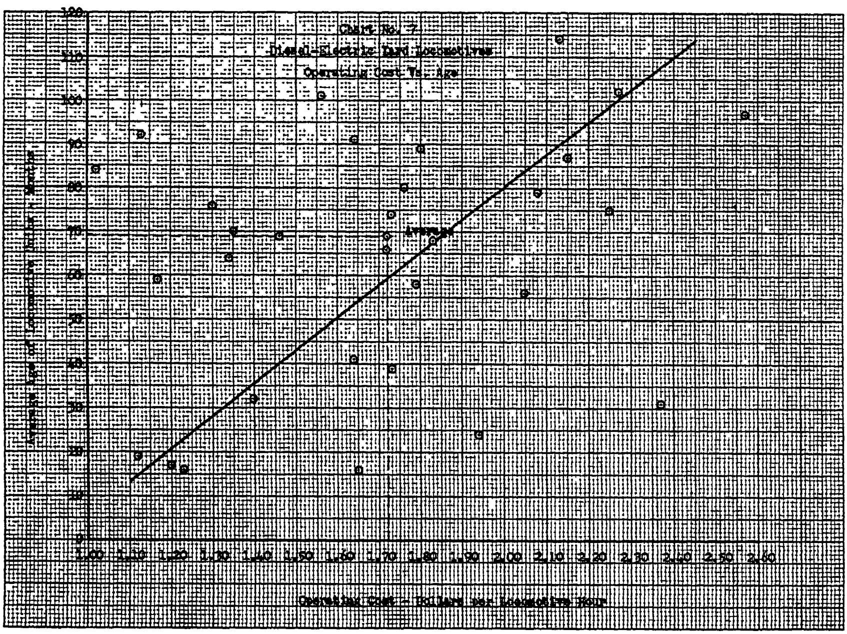


Chart No. 7
Diesel-Electric Yard Locomotives
Operating Cost Vs. Age
Average
Average Age of Locomotive Units - Months
Operating Cost - Dollars per Locomotive Hour

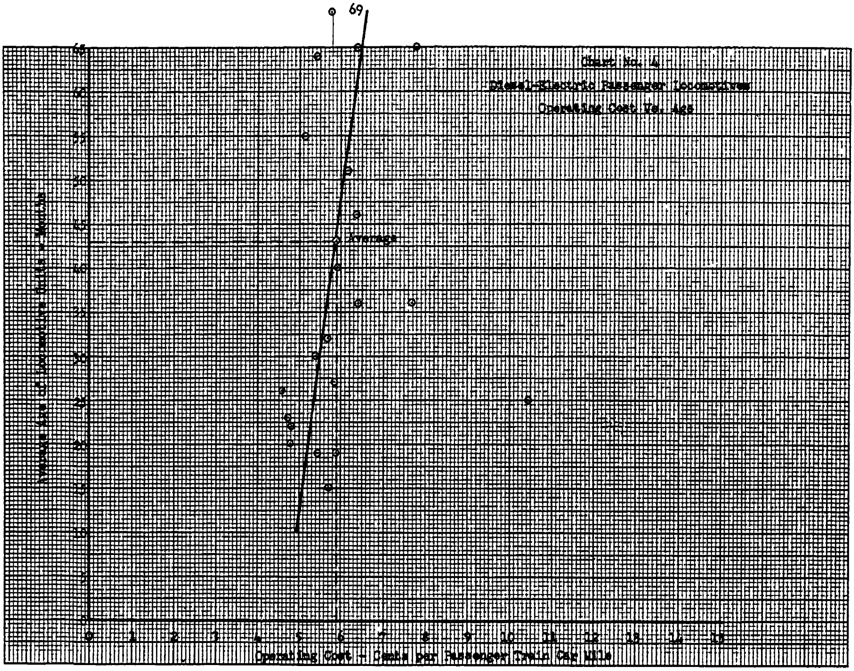


Chart No. 4
Diesel-Electric Passenger Locomotives
Operating Cost Vs. Age
Average
69
Operating Cost - Cents per Passenger Train Car Mile
Average Age of Locomotive Units - Months

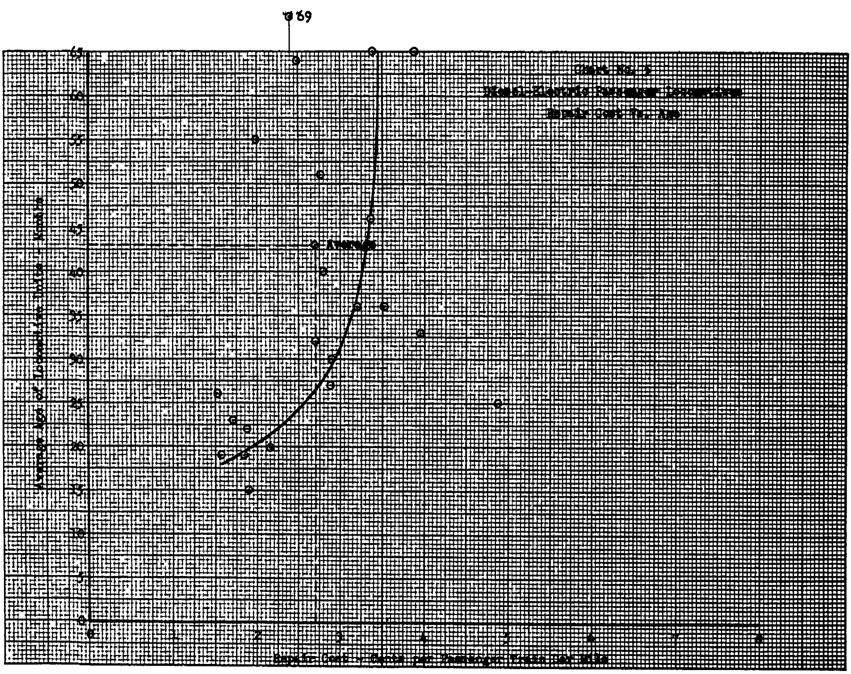


Chart No. 5
Diesel-Electric Passenger Locomotives
Repair Cost Vs. Age
Average
69
Repair Cost - Cents per Passenger Train Car Mile
Average Age of Locomotive Units - Months

TABLE I

DIESEL-ELECTRIC FREIGHT LOCOMOTIVE OPERATING COMPARISON
Period Ended February 28, 1949

RAILROAD CODE		A	B	C	D	E	F	G	H
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	7
Average Age of Loco. Units (Mo's.)		39	65	28	37	45	8	39	5
Average Miles Per Loco. Unit Per Mo.		11357	9580	12552	9198	8161	7726	7286	9130
% Hrs. Available of Hrs. in Period		86.3	85.4	-	76.7	79.2	85.9	-	83.1
% Hrs. Worked of Hrs. in Period		76.6	50.2	-	51.1	59.5	64.3	-	50.5
Average Train Miles Per Train Hour		24.8	25.4	28.7	26.9	22.7	19.6	-	26.3
Average Trailing MGTM Per Train Hour		102.6	81.6	111.7	64.4	62.0	65.1	-	80.8
Average Gross Tons Per Loco. Unit		1289	784	1027	1049	1096	1596	989	1503
Average Horsepower Per Unit		1400	1350	1422	1362	1354	1500	1357	1500
Fuel Consumption	Per MGTM	1.43	1.89	1.50	1.88	1.71	1.46	1.84	1.53
(In Gallons)	Per Loco. Unit Mi.	2.21	1.48	1.54	1.97	1.87	2.32	1.82	2.30
Lube Oil Consumption	Per MGTM	.019	.022	.013	.021	.031	.016	.022	.011
(In Gallons)	Per Loco. Unit Mi.	.023	.018	.013	.022	.034	.025	.022	.016
SIGNIFICANT OPERATING COSTS PER MGTM (Cents)									
Repairs		7.15	16.06	6.44	9.94	13.62	6.66	11.07	6.91
Fuel		15.11	17.67	16.53	20.39	17.23	14.72	18.49	17.84
Lubricants		1.03	1.23	.69	1.01	1.36	.79	.97	.64
Total		23.29	34.96	23.66	31.34	32.21	22.17	30.53	25.39
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)									
Repairs		10.77	12.59	6.62	10.42	14.93	10.63	10.95	10.38
Fuel		23.57	13.85	16.98	21.38	18.89	23.48	18.29	26.82
Lubricants		1.52	.96	.71	1.06	1.49	1.26	.96	.97
Total		35.86	27.40	24.31	32.86	35.31	35.37	30.20	38.17

TABLE I - Continued

RAILROAD CODE		I	J	K	L	M	N	O	P
OPERATING INDICATORS									
No. of Months Data Covers		12	2	12	12	12	12	12	12
Average Age of Loco. Units (Mo's.)		53	3	23	26	29	12	26	51
Average Miles Per Loco. Unit Per Mo.		10607	8109	7592	8908	11305	8947	10726	13707
% Hrs. Available of Hrs. in Period		86.8	96.8	81.0	86.8	82.9	97.4	-	84.6
% Hrs. Worked of Hrs. in Period		73.5	40.8	47.7	47.9	73.6	-	64.9	63.1
Average Train Miles Per Train Hour		22.2	20.8	18.6	24.9	26.1	23.8	25.5	29.3
Average Trailing MGTM Per Train Hour		61.9	50.0	38.5	73.5	83.2	59.5	78.0	126.9
Average Gross Tons Per Loco. Unit		703	946	948	1232	1100	1259	1156	1068
Average Horsepower Per Unit		1408	1500	1480	1443	1381	1500	1420	1350
Fuel Consumption	Per MGTM	2.39	1.77	2.11	1.72	1.67	1.57	1.47	1.50
(In Gallons)	Per Loco. Unit Mi.	1.68	1.68	2.00	2.12	1.84	1.98	1.70	1.60
Lube Oil Consumption	Per MGTM	.035	.008	.009	.018	.013	.013	.018	.013
(In Gallons)	Per Loco. Unit Mi.	.024	.008	.009	.022	.015	.016	.021	.014
SIGNIFICANT OPERATING COSTS PER MGTM (Cents)									
Repairs		16.24	4.99	17.66	11.38	7.61	3.78	9.48	6.38
Fuel		27.32	18.24	27.69	21.32	16.73	16.48	17.78	15.21
Lubricants		2.01	.34	.44	.85	.68	.64	.90	.67
Total		45.57	23.57	45.79	33.55	25.02	20.90	28.16	22.26
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)									
Repairs		11.41	4.72	16.74	14.01	8.38	4.76	10.96	6.82
Fuel		19.19	17.25	26.25	26.26	18.40	20.74	20.56	16.24
Lubricants		1.41	.32	.41	1.04	.75	.81	1.04	.72
Total		32.01	22.29	43.40	41.31	27.53	26.31	32.56	23.78

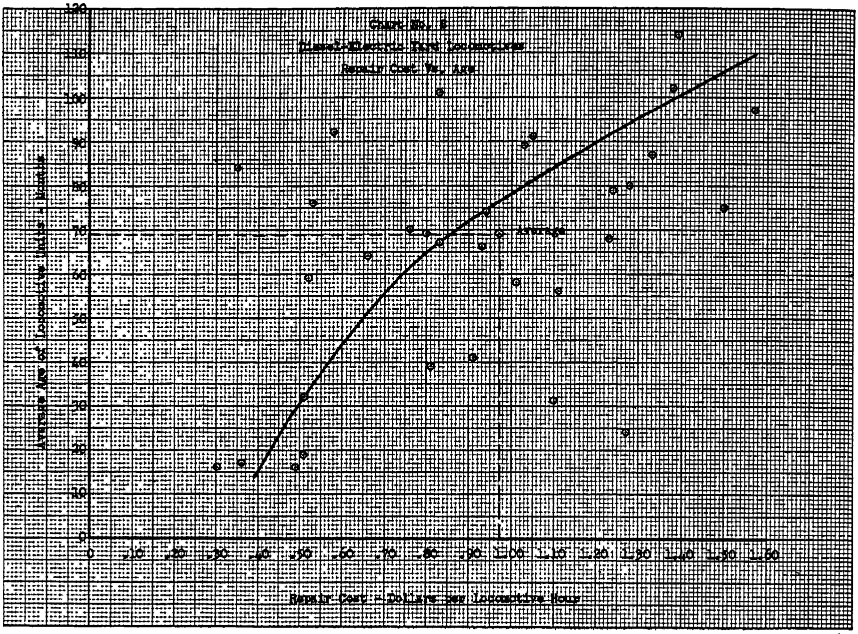


Chart No. 8
Diesel-Electric Yard Locomotives
Repair Cost Vs. Age
Average
Average Age of Locomotive Units - Months
0
10
20
30
40
50
60
70
80
90
100
110
120
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
Repair Cost - Dollars per Locomotive Hour

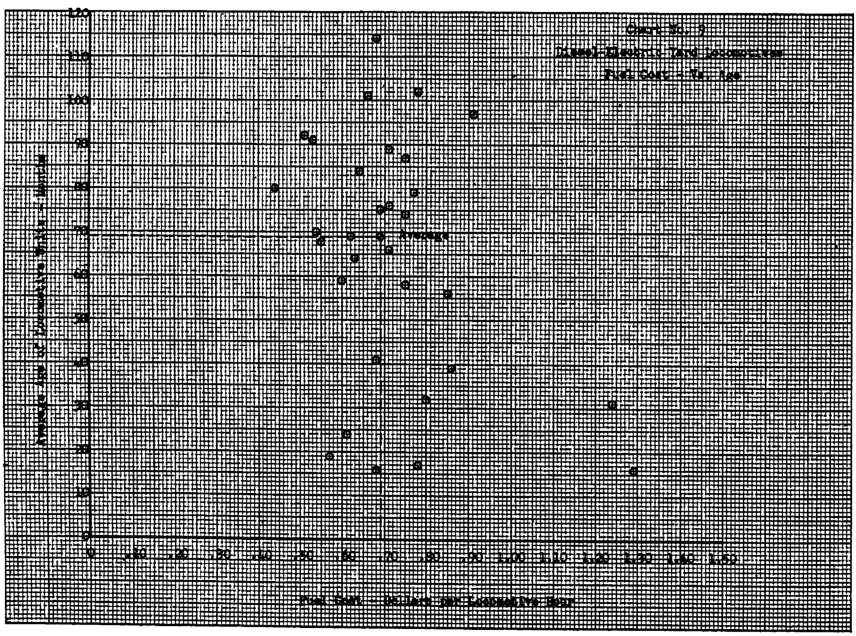


Chart No. 9
Diesel-Electric Yard Locomotives
Fuel Cost - Vs. Age
Average
Average Age of Locomotive Units - Months
0
10
20
30
40
50
60
70
80
90
100
110
120
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
1.10
1.20
1.30
1.40
1.50
Fuel Cost - Dollars per Locomotive Hour

TABLE I - Continued

RAILROAD CODE		A	B	C	D	E	F	G	H
ANALYSIS OF REPAIRS PER MGTM (Cents)									
Repairs - Engine:	Labor	2.45	2.76	2.34	-	2.91	1.37	-	1.09
	Material	1.42	4.39	1.56	-	2.40	1.76	-	.39
	Total	3.87	7.15	3.90	-	5.31	3.13	-	1.48
Repairs - Electrical:	Labor	.92	.91	.50	-	2.15	.84	-	1.19
	Material	.76	3.27	.82	-	1.62	.55	-	.48
	Total	1.68	4.18	1.32	-	3.77	1.39	-	1.67
Repairs - Other:	Labor	.75	2.21	.70	-	2.56	1.54	-	2.08
	Material	.85	2.52	.52	-	1.98	.60	-	1.68
	Total	1.60	4.73	1.22	-	4.54	2.14	-	3.76
Total Repair Labor		4.12	5.88	3.54	5.51	7.62	3.75	-	4.36
Total Repair Material		3.03	10.18	2.90	4.43	6.00	2.91	-	2.55
Total Repairs		7.15	16.06	6.44	9.94	13.62	6.66	11.07	6.91
Repairs (Cents) Per Gal. Fuel Consumed		5.01	8.49	4.30	5.30	7.97	4.57	6.02	4.52

RAILROAD CODE		I	J	K	L	M	N	O	P
ANALYSIS OF REPAIRS PER MGTM (Cents)									
Repairs - Engine:	Labor	3.64	1.94	5.94	3.27	2.60	-	-	-
	Material	2.13	.38	2.04	1.78	2.23	-	-	-
	Total	5.77	2.32	7.98	5.05	4.83	-	-	-
Repairs - Electrical:	Labor	2.28	1.33	1.89	1.14	.65	-	-	-
	Material	3.76	.03	1.35	1.94	1.18	-	-	-
	Total	6.04	1.36	3.24	3.08	1.83	-	-	-
Repairs - Other:	Labor	2.21	1.12	5.32	1.18	.33	-	-	-
	Material	2.22	.19	1.12	2.07	.62	-	-	-
	Total	4.43	1.31	6.44	3.25	.95	-	-	-
Total Repair Labor		8.13	4.39	13.15	5.59	3.58	2.65	-	2.90
Total Repair Material		8.11	.60	4.51	5.79	4.03	1.13	-	3.48
Total Repairs		16.24	4.99	17.66	11.38	7.61	3.78	9.48	6.38
Repairs (Cents) Per Gal. Fuel Consumed		6.79	2.81	8.38	6.61	4.55	2.40	6.45	4.26

TABLE I - Continued

RAILROAD CODE		Q	R	S	T	U	V	W
ANALYSIS OF REPAIRS PER MGTM (Cents)								
Repairs - Engine:	Labor	3.10	-	4.97	-	-	-	2.17
	Material	1.26	-	1.72	-	-	-	.55
	Total	4.36	-	6.69	-	-	-	2.72
Repairs - Electrical:	Labor	2.32	-	2.28	-	-	-	1.58
	Material	2.47	-	.90	-	-	-	1.22
	Total	4.79	-	3.18	-	-	-	2.80
Repairs - Other:	Labor	3.10	-	1.85	-	-	-	1.04
	Material	1.34	-	1.25	-	-	-	.64
	Total	4.44	-	3.10	-	-	-	1.68
Total Repair Labor		8.52	4.23	9.10	4.67	-	-	4.79
Total Repair Material		5.07	3.40	3.87	2.86	-	-	2.41
Total Repairs		13.59	7.63	12.97	7.53	8.53	5.27	7.20
Repairs (Cents) Per Gal. Fuel Consumed		6.44	5.11	8.45	4.98	5.20	2.78	4.05

RAILROAD CODE		X	Y	Z	AA	Average All Roads
ANALYSIS OF REPAIRS PER MGTM (Cents)						
Repairs - Engine:	Labor	-	-	-	-	2.89
	Material	-	-	-	-	1.65
	Total	-	-	-	-	4.54
Repairs - Electrical:	Labor	-	-	-	-	1.50
	Material	-	-	-	-	1.75
	Total	-	-	-	-	3.25
Repairs - Other:	Labor	-	-	-	-	1.83
	Material	-	-	-	-	1.21
	Total	-	-	-	-	3.04
Total Repair Labor		5.16	5.14	3.93	1.86	5.81
Total Repair Material		6.93	1.12	4.44	1.06	4.46
Total Repairs		12.09	6.26	8.37	2.92	10.16
Repairs (Cents) Per Gal. Fuel Consumed		-	3.93	4.54	1.80	5.68

TABLE I - Continued

RAILROAD CODE		Q	R	S	T	U	V	W
		OPERATING INDICATORS						
No. of Months Data Covers		12	12	12	12	12	11	12
Average Age of Loco. Units (Mo's.)		60	25	32	10	15	5	11
Average Miles Per Loco. Unit Per Mo.		10544	7563	6782	9549	9633	12806	9429
% Hrs. Available of Hrs. in Period		87.0	-	84.1	83.8	83.3	92.3	86.5
% Hrs. Worked of Hrs. in Period		54.8	-	66.9	71.8	48.4	55.3	77.0
Average Train Miles Per Train Hour		26.3	19.6	17.6	23.4	26.3	32.4	-
Average Trailing MGTM Per Train Hour		82.9	71.4	72.1	76.1	70.0	75.6	-
Average Gross Tons Per Loco. Unit		826	1402	1371	1477	1135	1017	1022
Average Horsepower Per Unit		1350	1460	1375	1500	1499	1500	1500
Fuel Consumption	Per MGTM	2.11	1.49	1.54	1.51	1.64	1.89	1.78
(In Gallons)	Per Loco. Unit Mi.	1.74	2.09	2.11	2.23	1.86	1.93	1.82
Lube Oil Consumption	Per MGTM	.025	.012	.018	.011	.021	.022	.014
(In Gallons)	Per Loco. Unit Mi.	.020	.017	.024	.016	.024	.022	.014
		SIGNIFICANT OPERATING COSTS PER MGTM (Cents)						
Repairs		13.59	7.63	12.97	7.53	8.53	5.27	7.20
Fuel		19.18	16.44	15.93	16.91	17.82	20.27	14.85
Lubricants		1.07	.58	.78	.56	1.10	1.10	.70
Total		33.84	24.65	29.68	25.00	27.45	26.64	22.75
		SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)						
Repairs		11.22	10.69	17.79	11.11	9.68	5.36	7.36
Fuel		15.84	23.04	21.84	24.97	20.21	20.61	15.17
Lubricants		.88	.81	1.06	.82	1.25	1.12	.72
Total		27.94	34.54	40.69	36.90	31.14	27.09	23.25

TABLE I - Continued

RAILROAD CODE		X	Y	Z	AA	Average All Roads
		OPERATING INDICATORS				
No. of Months Data Covers		11	4	2	9	-
Average Age of Loco. Units (Mo's.)		43	4	17	8	34
Average Miles Per Loco. Unit Per Mo.		9588	10508	12921	11212	9722
% Hrs. Available of Hrs. in Period		-	-	-	89.0	84.7
% Hrs. Worked of Hrs. in Period		-	-	-	58.4	58.9
Average Train Miles Per Train Hour		25.5	-	-	28.7	25.2
Average Trailing MGTM Per Train Hour		76.2	-	-	75.1	78.2
Average Gross Tons Per Loco. Unit		1078	1160	896	1270	1010
Average Horsepower Per Unit		1367	1500	1500	1500	1403
Fuel Consumption	Per MGTM	-	1.59	1.84	1.63	1.78
(In Gallons)	Per Loco. Unit Mi.	-	1.85	1.65	2.07	1.80
Lube Oil Consumption	Per MGTM	-	-	.018	.010	.019
(In Gallons)	Per Loco. Unit Mi.	-	-	.016	.013	.019
		SIGNIFICANT OPERATING COSTS PER MGTM (Cents)				
Repairs		12.09	6.26	8.37	2.92	10.16
Fuel		-	15.41	17.17	19.01	18.16
Lubricants		-	.96	.73	.45	.93
Total		-	22.63	26.27	22.38	29.25
		SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)				
Repairs		13.04	7.27	7.50	3.70	10.29
Fuel		-	17.88	15.39	24.15	18.42
Lubricants		-	1.12	.65	.58	.95
Total		-	26.27	23.54	28.43	29.66

TABLE II - Continued

RAILROAD CODE		Q	R	S	T	U	V	W	Avg. All Roads
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	11	12	2	-
Average Age of Loco. Units (Mo's.)		46	23	22	30	33	69	63	43
Average Miles Per Loco. Unit Per Mo.		17732	19650	26141	24124	17719	18102	14136	18517
% Hrs. Available of Hrs. in Period		-	83.0	79.3	81.5	-	-	-	79.6
% Hrs. Worked of Hrs. in Period		-	63.2	-	74.8	-	-	-	60.0
Average Train Miles Per Train Hour		51.8	42.6	55.2	-	49.7	41.7	-	46.7
Aver. Pass. Tr. Car Mi. Per Train Hour		597	520	736	-	556	489	-	518
Aver. Pass. Tr. Cars Per Loco. Unit		6.4	6.1	6.3	4.5	5.7	6.7	-	5.0
Aver. Horsepower Per Unit		1988	2000	1916	1998	2000	2000	1778	1798
Fuel Consumption	Per PTCM	.26	.30	.25	.28	-	.29	-	.29
(In Gallons)	Per Loco. Unit Mi.	1.65	1.82	1.59	1.26	-	1.94	1.42	1.44
Lube Oil Consumption	Per PTCM	.004	.003	.003	.003	-	.005	-	.003
(In Gallons)	Per Loco. Unit Mi.	.024	.018	.020	.013	-	.032	.026	.018
SIGNIFICANT OPERATING COSTS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs		3.36	1.72	1.88	2.90	3.97	2.40	-	2.71
Fuel		2.82	2.85	2.76	2.36	-	3.22	-	3.00
Lubricants		.17	.16	.17	.15	-	.19	-	.17
Total		6.35	4.73	4.81	5.41	-	5.81	-	5.88
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)									
Repairs		21.61	10.51	11.94	12.92	22.66	15.95	27.91	13.81
Fuel		18.15	17.41	17.48	10.48	-	21.42	12.35	15.14
Lubricants		1.11	.99	1.08	.68	-	1.25	1.48	.86
Total		40.87	28.91	30.50	24.08	-	38.62	41.74	29.81

TABLE II - Continued

RAILROAD CODE		A	B	C	D	E	F	G	H
ANALYSIS OF REPAIRS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs - Engine:	Labor	.64	.42	.46	-	.50	-	.36	-
	Material	.16	.14	.38	-	.32	-	.23	-
	Total	.80	.56	.84	-	.82	-	.59	-
Repairs - Electrical:	Labor	.29	.32	.20	-	.49	-	.29	-
	Material	.21	.46	.24	-	.31	-	.17	-
	Total	.50	.78	.44	-	.80	-	.46	-
Repairs - Other:	Labor	.29	.40	.33	-	.62	-	.63	-
	Material	.24	.42	.37	-	.64	-	.22	-
	Total	.53	.82	.70	-	1.26	-	.85	-
Total Repair Labor		1.22	1.14	.99	1.57	1.61	-	1.28	1.09
Total Repair Material		.61	1.02	.99	1.81	1.27	-	.62	.48
Total Repairs		1.83	2.16	1.98	3.38	2.88	2.70	1.90	1.57
Repairs (Cents) Per Gal. Fuel Consumed		5.65	6.16	7.23	12.19	10.28	10.41	6.34	4.46

RAILROAD CODE		I	J	K	L	M	N	O	P
ANALYSIS OF REPAIRS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs - Engine:	Labor	.76	.41	1.19	.63	.41	-	.63	.39
	Material	.80	.30	.36	.38	.50	-	.34	.34
	Total	1.56	.71	1.55	1.01	.91	-	.97	.73
Repairs - Electrical:	Labor	.46	.27	.40	.32	.24	-	.38	.31
	Material	.42	.33	.36	.89	.38	-	.29	.52
	Total	.88	.60	.76	1.21	.62	-	.67	.83
Repairs - Other:	Labor	.54	.80	1.73	.64	.43	-	.87	.60
	Material	.54	.66	.84	1.02	.52	-	.69	.63
	Total	1.08	1.46	2.57	1.66	.95	-	1.56	1.23
Total Repair Labor		1.76	1.48	3.32	1.59	1.08	.83	1.88	1.30
Total Repair Material		1.76	1.29	1.56	2.29	1.40	.70	1.32	1.49
Total Repairs		3.52	2.77	4.88	3.88	2.48	1.53	3.20	2.79
Repairs (Cents) Per Gal. Fuel Consumed		10.20	8.80	11.75	12.15	8.61	5.39	10.97	8.95

TABLE II

DIESEL-ELECTRIC PASSENGER LOCOMOTIVE OPERATING COMPARISON
Period Ended February 28, 1949

RAILROAD CODE		A	B	C	D	E	F	G	H
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	12
Average Age of Loco. Units (Mo's.)		19	20	55	65	27	32	15	19
Average Miles Per Loco. Unit Per Mo.		19361	18477	19864	15005	10967	16252	16598	11258
% Hrs. Available of Hrs. in Period		83.7	79.8	-	76.1	83.3	-	81.7	90.8
% Hrs. Worked of Hrs. in Period		78.2	64.7	-	51.6	61.9	-	59.4	51.2
Average Train Miles Per Train Hour		41.5	41.5	45.8	44.7	35.2	-	46.8	38.4
Aver. Pass. Tr. Car Mi. Per Train Hour		465	535	483	542	262	-	297	302
Aver. Pass. Tr. Cars Per Loco. Unit		3.7	4.3	5.6	5.3	6.4	4.6	5.1	5.8
Aver. Horsepower Per Unit		1500	1500	1879	2000	2000	1495	1664	1964
Fuel Consumption	Per PTCM	.32	.26	.27	.28	.28	.26	.30	.35
(In Gallons)	Per Loco. Unit Mi.	1.19	1.13	1.53	1.47	1.80	1.20	1.53	2.03
Lube Oil Consumption	Per PTCM	.003	.003	.003	.004	.003	.003	.002	.003
(In Gallons)	Per Loco. Unit Mi.	.012	.013	.015	.024	.019	.014	.009	.018
SIGNIFICANT OPERATING COSTS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs		1.83	2.16	1.98	3.38	2.88	2.70	1.90	1.57
Fuel		3.42	2.46	3.02	2.78	2.83	2.88	3.73	4.20
Lubricants		.21	.20	.13	.23	.14	.14	.09	.15
Total		5.46	4.82	5.13	6.39	5.85	5.72	5.72	5.92
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)									
Repairs		6.70	9.18	11.07	17.90	18.51	12.49	9.70	9.06
Fuel		12.53	10.47	16.90	14.73	18.20	13.32	19.02	24.21
Lubricants		.78	.86	.73	1.20	.38	.65	.45	.87
Total		20.01	20.51	28.70	33.83	37.59	26.46	29.17	34.14

TABLE II - Continued

RAILROAD CODE		I	J	K	L	M	N	O	P
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	12
Average Age of Loco. Units (Mo's.)		36	51	25	65	64	26	36	40
Average Miles Per Loco. Unit Per Mo.		15367	11634	11877	17434	19941	12753	20558	24172
% Hrs. Available of Hrs. in Period		76.6	89.1	83.4	71.8	73.2	96.4	81.9	80.1
% Hrs. Worked of Hrs. in Period		60.7	35.3	40.4	-	68.2	-	49.8	65.3
Average Train Miles Per Train Hour		27.5	44.2	40.1	47.4	49.1	41.9	52.8	50.3
Aver. Pass. Tr. Car Mi. Per Train Hour		241	581	236	501	430	406	632	633
Aver. Pass. Tr. Cars Per Loco. Unit		4.2	6.3	3.0	4.6	5.7	6.7	5.4	3.6
Aver. Horsepower Per Unit		1566	2000	1491	1842	1824	2000	2000	1529
Fuel Consumption	Per PTCM	.34	.31	.41	.32	.29	.28	.29	.31
(In Gallons)	Per Loco. Unit Mi.	1.44	1.98	1.25	1.48	1.65	1.91	1.56	1.11
Lube Oil Consumption	Per PTCM	.004	.004	.002	.004	.002	.002	.004	.005
(In Gallons)	Per Loco. Unit Mi.	.018	.024	.006	.017	.011	.016	.020	.017
SIGNIFICANT OPERATING COSTS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs		3.52	2.77	4.88	3.88	2.48	1.53	3.20	2.79
Fuel		3.89	3.23	5.47	3.70	2.89	2.97	3.04	2.96
Lubricants		.23	.14	.09	.23	.09	.11	.20	.20
Total		7.64	6.14	10.44	7.81	5.46	4.61	6.44	5.95
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE UNIT MILE (Cents)									
Repairs		14.71	17.41	14.64	18.02	14.19	10.30	17.12	9.94
Fuel		16.27	20.32	16.43	17.20	16.50	20.00	16.28	10.55
Lubricants		.96	.87	.28	1.05	.54	.77	1.08	.72
Total		31.94	38.60	31.35	36.27	31.23	31.07	34.48	21.21

TABLE III - Continued

RAILROAD CODE		I	J	K	L	M	N	O	P
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	12
Average Age of Loco's. (Months)		75	66	31	59	87	74	24	102
Average Loco. Hours Worked Per Month		617	595	478	596	525	570	494	594
% Hrs. Available of Hours in Period		90.6	93.8	88.4	9.29	93.9	95.3	85.8	-
% Hrs. Worked of Hours in Period		83.7	77.8	65.5	81.7	71.9	78.2	68.7	81.2
Average Horsepower Per Locomotive		756	892	1363	774	675	885	605	785
Gallons of Fuel Per Locomotive Hour		5.98	6.52	9.34	5.10	7.46	7.09	4.54	7.60
Pints of Lubricating Oil Per Loco. Hr.		.980	1.090	.545	1.012	1.084	.637	.745	1.552
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE HOUR (Dollars)									
Repairs		1.50	.93	1.10	.52	1.33	.94	1.27	1.38
Fuel		.69	.71	1.24	.60	.75	.75	.61	.78
Lubricants		.06	.08	.03	.05	.07	.04	.06	.11
Total		2.25	1.72	2.37	1.17	2.15	1.73	1.94	2.27
ANALYSIS OF REPAIRS PER LOCOMOTIVE HOUR (Dollars)									
Repairs - Engine:	Labor	-	.21	.36	.18	.29	-	.25	-
	Material	-	.20	.11	.10	.50	-	.44	-
	Total	-	.41	.47	.28	.79	-	.69	-
Repairs - Electrical:	Labor	-	.11	.12	.06	.11	-	.18	-
	Material	-	.13	.03	.04	.20	-	.18	-
	Total	-	.24	.15	.10	.31	-	.36	-
Repairs - Other:	Labor	-	.13	.36	.07	.12	-	.16	-
	Material	-	.15	.12	.07	.11	-	.06	-
	Total	-	.28	.48	.14	.23	-	.22	-
Total Repair Labor		-	.45	.84	.31	.52	.40	.59	-
Total Repair Material		-	.48	.26	.21	.81	.54	.68	-
Total Repairs		1.50	.93	1.10	.52	1.33	.94	1.27	1.38
Repairs (Cents) Per Gal. Fuel Consumed		25.11	14.21	11.77	10.23	17.90	13.23	28.10	18.18

TABLE III - Continued

RAILROAD CODE		Q	R	S	T	U	V	W	
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	12
Average Age of Loco's. (Months)		97	17	41	114	58	91	56	16
Average Loco. Hours Worked Per Month		474	700	582	566	499	539	614	646
% Hrs. Available of Hours in Period		83.2	96.1	90.5	91.4	86.4	90.8	93.2	96.6
% Hrs. Worked of Hours in Period		64.9	96.0	80.3	77.7	68.7	73.9	84.3	90.7
Average Horsepower Per Locomotive		927	1000	1000	937	769	739	892	1004
Gallons of Fuel Per Locomotive Hour		8.18	5.81	6.66	6.89	6.73	5.08	7.41	7.20
Pints of Lubricating Oil Per Loco. Hr.		1.805	.793	.668	1.044	.868	1.104	1.449	.987
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE HOUR (Dollars)									
Repairs		1.57	.36	.91	1.39	1.01	1.05	1.11	.49
Fuel		.91	.78	.68	.68	.75	.53	.85	.68
Lubricants		.09	.06	.05	.06	.03	.06	.09	.06
Total		2.57	1.20	1.64	2.13	1.79	1.64	2.05	1.23
ANALYSIS OF REPAIRS PER LOCOMOTIVE HOUR (Dollars)									
Repairs - Engine:	Labor	.37	.12	-	.21	-	.53	-	-
	Material	.36	.06	-	.26	-	.14	-	-
	Total	.73	.18	-	.47	-	.67	-	-
Repairs - Electrical:	Labor	.21	.04	-	.13	-	.14	-	-
	Material	.11	.01	-	.26	-	.04	-	-
	Total	.32	.05	-	.39	-	.18	-	-
Repairs - Other:	Labor	.37	.08	-	.33	-	.11	-	-
	Material	.15	.05	-	.20	-	.09	-	-
	Total	.52	.13	-	.53	-	.20	-	-
Total Repair Labor		.95	.24	.53	.67	.49	.78	.48	.29
Total Repair Material		.62	.12	.38	.72	.52	.27	.63	.20
Total Repairs		1.57	.36	.91	1.39	1.01	1.05	1.11	.49
Repairs (Cents) Per Gal. Fuel Consumed		19.20	6.17	13.71	20.25	15.07	20.66	14.93	6.81

TABLE II - Continued

RAILROAD CODE		Q	R	S	T	U	V	W	Avg. All Roads
ANALYSIS OF REPAIRS PER PASSENGER TRAIN CAR MILE (Cents)									
Repairs - Engine:	Labor	-	-	-	.62	-	-	-	.49
	Material	-	-	-	.27	-	-	-	.36
	Total	-	-	-	.89	-	-	-	.85
Repairs - Electrical:	Labor	-	-	-	.43	-	-	-	.30
	Material	-	-	-	.22	-	-	-	.43
	Total	-	-	-	.65	-	-	-	.73
Repairs - Other:	Labor	-	-	-	.68	-	-	-	.57
	Material	-	-	-	.68	-	-	-	.61
	Total	-	-	-	1.36	-	-	-	1.18
Total Repair Labor		1.57	.89	-	1.73	1.64	-	-	1.40
Total Repair Material		1.79	.83	-	1.17	2.33	-	-	1.49
Total Repairs		3.36	1.72	1.88	2.90	3.97	2.40	-	2.71
Repairs (Cents) Per Gal. Fuel Consumed		13.09	5.77	7.49	10.28	-	8.21	19.59	9.32

TABLE III

DIESEL-ELECTRIC YARD LOCOMOTIVE OPERATING COMPARISON
Period Ended February 28, 1949

RAILROAD CODE		A	B	C	D	E	F	G	H
OPERATING INDICATORS									
No. of Months Data Covers		12	12	12	12	12	12	12	12
Average Age of Loco's. (Months)		101	70	76	84	68	79	89	39
Average Loco. Hours Worked Per Month		624	610	622	684	566	615	566	552
% Hrs. Available of Hours in Period		93.4	95.0	92.7	95.0	94.0	-	91.5	94.7
% Hrs. Worked of Hours in Period		85.6	83.6	85.4	93.7	77.8	-	77.5	75.7
Average Horsepower Per Locomotive		701	838	861	1000	745	1017	715	954
Gallons of Fuel Per Locomotive Hour		6.22	5.59	6.41	5.82	5.46	7.21	6.10	7.05
Pints of Lubricating Oil Per Loco. Hr.		.831	.612	.881	.556	.938	1.248	.799	1.133
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE HOUR (Dollars)									
Repairs		.83	.76	.53	.35	1.23	1.24	1.03	.81
Fuel		.66	.54	.71	.64	.55	.77	.71	.86
Lubricants		.07	.05	.06	.03	.05	.07	.06	.06
Total		1.56	1.35	1.30	1.02	1.83	2.08	1.80	1.73
ANALYSIS OF REPAIRS PER LOCOMOTIVE HOUR (Dollars)									
Repairs - Engine:	Labor	.22	.10	.15	-	-	-	.34	-
	Material	.15	.18	.12	-	-	-	.23	-
	Total	.37	.28	.27	-	-	-	.57	-
Repairs - Electrical:	Labor	.11	.05	.06	-	-	-	.09	-
	Material	.08	.12	.07	-	-	-	.12	-
	Total	.19	.17	.13	-	-	-	.21	-
Repairs - Other:	Labor	.13	.17	.06	-	-	-	.16	-
	Material	.14	.14	.07	-	-	-	.09	-
	Total	.27	.31	.13	-	-	-	.25	-
Total Repair Labor		.46	.32	.27	.15	.64	-	.59	.51
Total Repair Material		.37	.44	.26	.20	.59	-	.44	.30
Total Repairs		.83	.76	.53	.35	1.23	1.24	1.03	.81
Repairs (Cents) Per Gal. Fuel Consumed		13.39	13.66	8.33	5.98	22.56	17.21	16.89	11.52

(text continued from page 98)
32 groups of yard locomotives are included. The basic figures were supplied by the operating railways and the tables compiled by the manufacturer.

The series of nine charts graphically present the effect of age in each of the three services on operating as well as on repair and fuel costs which combine with lubricating expense to form the total operating cost. Expense for lubrication is relatively minor and not judged of sufficient moment to warrant its presentation graphically. It is noted from the plotted charts that in some instances curves can be drawn, although the slopes of those curves are subject to individual judgment. Generally speaking, this is true of those curves relating to freight and passenger locomotives. On the other hand, the scattered pattern of the plotted yard locomotive data renders the curves drawn of doubtful value, while in one instance, Yard Fuel Costs versus Age, a vertical band rather than a curve is indicated.

Your committee deeply regrets its inability to obtain operating indicators and significant operating costs for modern steam power to afford comparison with those tabulated in Tables I, II, and III. Several possible sources of such data were approached and it was learned in each instance that those railways do not separate the values desired between old and new power. While the steam–diesel–electric comparison originally sought is not available, the accompanying data are submitted as a basis for evaluating the economics of the diesel-electric locomotive.

Report on Assignment 6

Cost of Railway Transportation and Operation Over the Past 100 Years; Principal Controlling Elements and Economic Significance

R. L. Milner (chairman, subcommittee), W. E. Chapman, Miss Olive W. Dennis, C. H. Fox, Fred Lavis, C. P. Richardson, R. W. Rogers, E. H. Roth, A. L. Sams, H. M. Shepard, J. E. Teal, F. G. Walter, H. P. Weidman, J. A. Wood, J. S. Worley.

This is a final report submitted as information.

When the present phase of the subcommittee assignment was first considered, the relationships,

1. National income to railroad business volume, and
2. Railroad business volume to railroad expenses

were proposed for analysis. This was to be a step-by-step development, with the immediate purpose being a study of the manner in which railroad business volume followed national income.

The purpose of the study was to furnish a basis for estimating railroad business volume when the value of national income was given for a period in the future. Such estimates are made by the Federal Reserve Board, by bureaus of the Interstate Commerce Commission and others, and may be based on estimates of employment, and the productivity of labor and other factors.

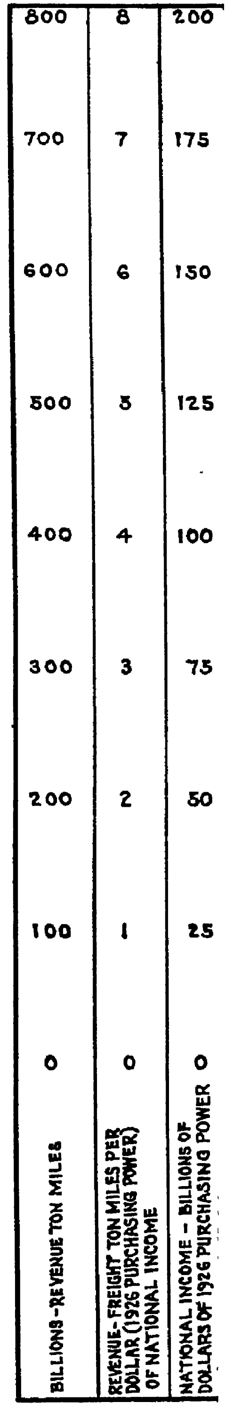
Transportation in general is an integral part of our industrial development and progress, and is a reliable indicator of national prosperity. The same may be said of railroad transportation, to the extent that it fills a portion of the national transportation needs. Therefore, in order to properly study the relationship between national income

TABLE III - Continued

RAILROAD CODE	Y	Z	AA	BB	CC	DD	EE	FF
OPERATING INDICATORS								
No. of Months Data Covers	12	11	12	11	12	4	3	2
Average Age of Loco's. (Months)	64	69	80	67	92	16	19	32
Average Loco. Hours Worked Per Month	596	568	660	592	657	510	691	603
% Hrs. Available of Hours in Period	90.1	87.5	92.8	-	-	92.8	-	-
% Hrs. Worked of Hours in Period	82.3	77.9	90.4	81.5	90.0	70.1	94.7	85.2
Average Horsepower Per Locomotive	727	895	926	867	600	950	1000	1000
Gallons of Fuel Per Locomotive Hour	5.65	5.59	-	-	4.44	10.94	5.24	8.23
Pints of Lubricating Oil Per Loco. Hr.	.840	.600	-	-	.422	.766	.458	1.178
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE HOUR (Dollars)								
Repairs	.66	.80	1.28	.83	.58	.30	.51	.51
Fuel	.63	.62	.44	-	.51	1.29	.57	.80
Lubricants	.05	.04	.04	-	.04	.06	.04	.09
Total	1.34	1.46	1.76	-	1.13	1.65	1.12	1.40
ANALYSIS OF REPAIRS PER LOCOMOTIVE HOUR (Dollars)								
Repairs - Engine: Labor	-	-	-	-	-	-	-	-
Material	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
Repairs - Electrical: Labor	-	-	-	-	-	-	-	-
Material	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
Repairs - Other: Labor	-	-	-	-	-	-	-	-
Material	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-
Total Repair Labor	-	-	-	.39	-	.15	-	.27
Total Repair Material	-	-	-	.44	-	.15	-	.24
Total Repairs	.66	.80	1.28	.83	.58	.30	.51	.51
Repairs (Cents) Per Gal. Fuel Consumed	11.60	14.29	-	-	13.06	2.75	9.78	6.19

TABLE III - Continued

RAILROAD CODE	Average All Roads
OPERATING INDICATORS	
No. of Months Data Covers	-
Average Age of Loco's. (Months)	69
Average Loco. Hours Worked Per Month	577
% Hrs. Available of Hours in Period	91.1
% Hrs. Worked of Hours in Period	79.7
Average Horsepower Per Locomotive	832
Gallons of Fuel Per Locomotive Hour	6.76
Pints of Lubricating Oil Per Loco. Hr.	1.014
SIGNIFICANT OPERATING COSTS PER LOCOMOTIVE HOUR (Dollars)	
Repairs	.97
Fuel	.69
Lubricants	.06
Total	1.72
ANALYSIS OF REPAIRS PER LOCOMOTIVE HOUR (Dollars)	
Repairs - Engine: Labor	.25
Material	.25
Total	.50
Repairs - Electrical: Labor	.10
Material	.11
Total	.21
Repairs - Other: Labor	.16
Material	.12
Total	.28
Total Repair Labor	.48
Total Repair Material	.47
Total Repairs	.97
Repairs (Cents) Per Gal. Fuel Consumed	14.78



800
700
600
500
400
300
200
100
0
BILLIONS - REVENUE TON MILES
8
7
6
5
4
3
2
1
0
REVENUE - FREIGHT TON MILES PER DOLLAR (1926 PURCHASING POWER) OF NATIONAL INCOME
200
175
150
125
100
75
50
25
0
NATIONAL INCOME - BILLIONS OF DOLLARS OF 1926 PURCHASING POWER

and railroad business volume, it is first necessary to relate national income to a unit such as revenue ton-miles and passenger-miles for all types of transportation, and at the same time to determine the share and the trend of total transportation service provided by the railroads.

The statistics of total transportation services provided thus far are too fragmentary to be of real value. Until such are developed, it will be necessary to show the relationship as between national income and railroad business volume, with only general reasons given to explain the wider variations in the trends of each.

This is mentioned because of the fact that the total transportation picture is made up of services performed by the steam railroads, electric inter-urban railroads, water carriers, motor carriers, oil pipe lines, air carriers, and the passenger automobile. The part that each plays is a measure of its development, ability to provide particular service, and suddenly expanded requirements such as during the recent World War.

At this time it will probably be simpler if the study is confined to freight transportation, which is closely related to production volume. As production volume is dependent on purchasing power, it is obvious that national income must be measured in dollars of constant purchasing power if a true relationship between the national income and production volume is to be had. The last report of this subcommittee, printed in the Proceedings, Vol. 49, 1948, page 28, related many of its statistics to dollars of 1926 purchasing power which will be used herein. This dollar had about the same purchasing power as the 1944 dollar, but has since declined rapidly, until in 1947 it had a value of 0.7941 of the 1926 dollar.

This present report is confined to the presentation and general discussion of statistics shown by the tables and chart. These statistics show from 1889 to date, where available,

1. Railroad revenue freight ton-miles and ton-miles of other carriers.
2. Realized national income in current dollars and in dollars of 1926 purchasing power (note these are somewhat revised from 1909 compared with previous report).

   Ratio of 1 to 2 next above.

Population data appearing in the Proceedings, Vol. 29, 1928, have been plotted on the present chart.

The limited statistics so far available preclude any satisfactory deductions at this time.

National Income

This comparison shows that population and national income (1926 basis) followed roughly a parallel and rising trend from 1899 until about 1930 with several sizeable variations.

These variations occurred in 1909–1910, when national income increased following the 1907 depression; also, in 1916–1917, when business volume was accelerated during World War I. The depression of 1920–1921 was reflected in a sizeable contraction in national income in the years 1920–1922.

The business spurt in the year 1929 showed a similar spurt in national income, following which a reversal during the depression years 1930 to 1933 may be noted. Income did not again return to its earlier pattern, as indicated on this chart, until about 1940, although it closely approached it in 1937.

A strong increasing trend in national income beginning in 1934, continued through to 1944, with the exception of 1937. This rising trend, which brought national income to an all time peak in 1944, turned downward but continued at very high levels through 1947.

TABLE 1.—NATIONAL INCOME AND REVENUE TON-MILES FOR RAILROADS OF THE UNITED STATES 1889–1947

	Year	Revenue Ton-Miles–	*Realized National Income* Current Dollars[1]	Dollars of 1926 Purchasing Power–	Ratio Revenue Ton-Miles per $1000 National Income
		000's	000,000's	000,000's	
	(1)	(2)	(3)	(4)	(5)
	1899	71,000,000[3]	10,701	23,675	3.3345
6–30	1890	76,207,047	[2]	[2]	
"	1	81,073,784	[2]	[2]	
"	2	88,241,050	[2]	[2]	
"	3	93,588,112	[2]	[2]	
"	4	80,335,105	[2]	[2]	
"	5	85,227,516	[2]	[2]	
"	6	95,328,360	[2]	[2]	
"	7	95,139,022	[2]	[2]	
"	8	114,077,576	[2]	[2]	
"	9	123,667,257	15,364	36,066	3428.9
"	1900	141,596,551	16,158	36,557	3873.3
"	1	147,077,136	17,170	37,903	3880.4
"	2	157,289,370	18,444	39,750	3957.0
"	3	173,221,279	19,595	40,319	4296.3
"	4	174,522,090	20,090	41,767	4178.5
"	5	186,463,110	21,428	44,549	4185.6
"	6	215,877,551	23,165	46,610	4631.6
"	7	236,601,390	24,403	46,482	5090.2
"	8	218,381,553	23,458	46,636	4682.7
"	9	218,802,987	28,700	58,100	3766.0
"	1910	255,016,915	30,400	58,300	4374.2
"	1	253,783,700	30,500	56,600	4483.8
"	2	264,080,742	32,900	60,600	4357.8
"	3	301,730,291	34,800	62,300	4843.2
"	4	288,637,042	33,900	59,700	4834.8
"	5	277,134,816	37,000	64,500	4296.7
"	6	343,477,348			
12–31	6	366,173,174	44,800	72,700	5036.8
"	7	398,263,062	53,700	74,100	5374.7
"	8	408,778,061	58,300	68,600	5958.9
"	9	367,161,371	68,200	69,700	5267.7
"	1920	413,698,749	59,500	61,300	6748.8
"	1	309,533,365	51,700	51,200	6045.6
"	2	342,187,536	59,500	62,800	5448.8
"	3	416,255,550	69,500	72,100	5773.3
"	4	391,945,037	69,100	71,500	5481.7
"	5	417,418,464	73,700	74,300	5618.0
"	6	447,443,627	76,600	76,600	5841.3
"	7	432,013,979	75,900	77,400	5581.6
"	8	436,086,747	78,700	81,100	5377.1
"	9	450,189,394	87,355	90,100	4996.6
"	1930	385,815,376	75,003	77,100	5004.1
"	1	311,072,637	58,873	68,500	4541.2
"	2	235,308,521	41,690	54,000	4357.6
"	3	250,651,190	39,584	54,200	4624.6
"	4	270,291,541	48,613	64,200	4210.1
"	5	283,637,058	56,789	73,200	3874.8
"	6	341,181,596	66,941	85,400	3995.1

national income in 1907, in 1913, in 1919, and in 1921 have been reflected on a larger scale in the ton-mile trend.

However, a significant change seems to occur about 1929, and quite noticeably thereafter. The two lines showing ton-miles and national income, begin to approach each other, and beginning with 1931, follow the same general pattern. The significance of this will be brought out in the following discussion of the ratio line of the chart.

This line simply reflects the ton-miles per dollar of national income. For the entire period 1899 to 1947 the average ton-miles per dollar (1926 basis) of national income has been approximately 4.5. If this had been constant throughout this period, the ratio line would have been a horizontal line at the point 4.5.

From 1899 to 1920 the ton-miles per dollar of national income showed an increase from 3.3 to 6.75, with sizeable reversals in 1907–1908, and in 1914 after a resumption of the upward trend in 1910, and reversal in 1919 immediately following World War I.

From 1920 on, the ratio of ton-mile-per-dollar-of-income changed from a rising to a declining trend, which, with moderate reversal principally in 1923 and in 1925–1926, continued on through 1938. This represented an overall decline in the ratio of ton miles per dollar from 6.75 in 1920 to 3.54 in 1938. This was but slightly different than the ratio of 3.33 in 1889.

Many factors are responsible for this change, and it is hoped that additional information on total ton-miles of all transportation agencies may help in its analysis at such future date as they may become available.

An upward trend in the ratio line was resumed in 1939, reaching 4.33 ton-miles-per-dollar in 1942, when a downward trend carried the ratio to 3.66 in 1946. The ratio in 1947 increased to 4.09 ton-miles-per-dollar.

In a general way, it may be said that ton-miles vary with national income, but that the increase per additional dollar of national income has been in a generally declining phase since 1920, whereas, prior to that time it was in a rising phase.

It will eventually be desirable to determine the primary cause of this changed trend; and it will be necessary, among other things, to explain the effect of competitive transportation agencies upon it. Scattered but not sufficient data from which to make deductions, are shown in Table 2 and indicated on the chart for freight traffic handled by carriers.

Should more complete data be later developed for these agencies, particularly for the years since 1920, it would be desirable at such time to determine the relationship between volumes of freight handled by railroads and by other carriers.

Report of Assignment 7

Yards; Effect of Their Location on the Economics of Railway Location and Operation, Collaborating with Committee 14

W. T. Rice (chairman, subcommittee), Herbert Ashton, F. C. Berghaus, W. E. Chapman, J. T. Fitzgerald, J. M. Fox, W. M. Jaekle, J. M. MacBride, F. H. McGuigan, Jr., R. L. Milner, F. N. Nye, F. B. Peter, C. P. Richmond, H. C. Rowe, A. E. Street, J. F. Swenson, H. D. Walker, H. P. Weidman, H. L. Woldridge, W. H. Wood, J. S. Worley.

This is a final report presented as information.

For the purpose of this study your committee has assumed the case of a freight classification yard location. The type of yard reported on is one in which freight trains are

TABLE 1. (continued)

Year (1)	Revenue Ton-Miles—000's (2)	Realized National Income: Current Dollars[1] 000,000's (3)	Realized National Income: Dollars of 1926 Purchasing Power—000,000's (4)	Ratio Revenue Ton-Miles per $1000 National Income (5)
" 7	362,815,382	73,627	90,700	4000.2
" 8	291,866,410	67,375	84,500	3454.0
" 9	335,375,486	72,532	92,300	3633.5
" 1940	375,368,718	81,347	102,600	3658.6
" 1	477,576,232	103,834	124,800	3826.7
" 2	640,992,240	136,486	148,000	4331.0
" 3	730,132,280	168,262	172,000	4245.0
" 4	740,586,092	182,407	183,700	4031.5
" 5	684,148,448	181,731	178,900	3824.2
" 6	594,942,799	179,289	162,700	3656.7
" 7	657,877,829	202,500	160,800	4091.3

[1] Year ending 12-31.
[2] Not available.
[3] Partially interpolated.

TABLE 2.—COMMERCIAL INTERCITY FREIGHT TRAFFIC IN UNITED STATES*
1926, 1939, 1948

Year	Ton Miles (Millions): Great Lakes[1]	Rivers and Canals	Motor Trucks	Oil Pipe Lines	Electric Rail-roads	Air Carriers	Total	Ratio Ton-miles per $1000[4] National Income
1926	.. 83,000	9,542	23,530	21,700	1,313	...	139,085	1815.7
1939	.. 69,060	19,937	43,000	63,107	725	11	195,840	2121.8
1940	.. 87,593	22,412	51,003	67,270	818	14	229,110	2233.0
1941	..104,100	26,815	57,123	77,818	965	18	266,839	2138.1
1942	..112,393	26,398	50,207	74,730	1,166	34	264,928	1790.1
1943	..104,006	26,306	48,199	96,257	1,295	51	276,114	1605.3
1944	..105,620	31,385	49,308	132,336	1,339	67	320,005	1742.0
1945	..102,091	29,709	56,155	123,293	1,227	87	312,562	1747.1
1946	.. 87,081	27,951	64,300	92,490	1,027	71	272,920	1677.4
1947[2]	..104,000	35,000	77,900	104,100	1,080	100	322,180	2003.6
1948[3]	..105,000	44,000	90,000	118,000	1,000	150	358,150	.....

* Includes intercity freight traffic by private as well as contract and other carriers except coastwise and intercoastal traffic.
[1] U. S. domestric traffic only.
[2] Preliminary, subject to revision.
[3] Estimated.
[4] Dollars of 1926 purchasing power.
Sources: Various.

Railroad Revenue Freight Ton-Miles

Revenue freight ton-miles, while following in a general way the pattern of national income trends, showed considerably more variation. It may be noted that from 1899 to 1929, revenue freight ton-miles increased at a much more rapid rate than either the income or population trend line. It may also be noted that the increases or decreases in

over-all time consumed will be decreased accordingly. It is often necessary that auxiliary yards be provided in connection with classification yards in large industrial areas to facilitate delivery to destination siding.

(f) Distance from Seaport or Inland Port

The reconsignment of freight depending on ships and port facilities, as experienced in the past war, developed the necessity of having classification yards accessible to large ports in order that freight traffic can be classified according to the requirements of the port authorities. In times of national emergency, when so much freight is being dispatched to seaports, it is highly important that facilities be available to classify this traffic according to the requirements of the port and thereby increase the loading speed of ships. This in turn increases car turn-around and allows some commodities to be dispatched from various parts of the country and assembled at a convenient point near the port for prompt delivery at ships side, as called for. In peace time this same principle applies.

(g) Location at Junction of Points of Main Lines or Interchange Points

In the interest of expediting overall freight movement classification yards should be located at points where traffic must pass in moving to destination. A yard located at junction of lines will allow trains to be assembled from traffic accumulated from all lines so that the expeditious movement to a distant point can be accomplished. At interchange points traffic must be classified in accordance with the lines that serve the area and this feature is highly important in developing the location of the yard that will give the maximum road haul and also reduce per diem payments.

(h) Sufficient Area to Expand

As the traffic increased so many yards have grown to a point where they can no longer be expanded, and the operation is badly hampered by crowded or congested facilities. Increased train lengths have resulted in the need for longer track at both receiving and dispatching ends of yards. Although the size may appear adequate at the time of construction, the rapid increase in population and growth of industry make it necessary that all large facilities embrace an area for potential expansion. This has been recently emphasized and has also become an increasing problem in large cities where the yards are surrounded by industrial areas and highways. Further development is prohibited, and it is necessary to look for new locations elsewhere.

(i) Switching Limits

In any yard location the current agreement with employees must be considered, because the present switching limit locations can result in exorbitant wage costs unless this feature is developed to a satisfactory conclusion between labor and management. This is particularly true in our large cities where present switching limits are definitely defined and any further development would necessitate the changing of current contracts.

(j) Distance Between Yards to Secure Maximum Efficiency of Power and Crews

Most of the present contracts with operating brotherhoods require payment on the basis of miles or hours. It frequently occurs that the crew on a freight train moving between distant cities will make two to three days' pay in one run, as the original contracts established 100 miles a day's work. Freight trains frequently run 200 to 250 miles with the same crew. The increased speed of traffic serves to offset the financial burden of moving trains longer distances as enumerated above. Yards must be located

broken down and reassembled into destination blocks, running repairs are made to freight cars and locomotives, rest facilities are provided for road crews, icing facilities and livestock facilities are available, and clerical work incident to the classification and preparation of records of freight trains is performed.

1. Economics of Operation As Affected By

(a) Yard Terrain

It is desirable that yards be located in areas that will afford the proper gradient for traffic flowing in both directions to reduce operating costs. In a large yard it is undesirable to have grades other than the grades that are introduced as a part of the hump installations. It is generally desirable that the yard not be at the bottom of a hill from which freight trains have to start on an ascending grade. Yards should be well drained and located in areas where drainage facilities are available or can be provided at nominal cost.

(b) Adequate Size

After exhaustive study as to the traffic to be handled through the proposed facility, it should be designed to carry the maximum daily average number of cars handled during an extended period. It may not be desirable or necessary to build the entire facility initially, but if the design is correct in the first instance the yard can be enlarged along well planned lines as the traffic increases so as to assure a practical and economical operating facility.

(c) Labor Availability

The supply of labor should be considered in any development. The cost of transporting labor to outlying facilities has become quite a burden in some instances. Labor demands should be weighed against prospective sites to see which site will afford sufficient labor, as well as the type of personnel adaptable to railroad employment.

(d) Availability of Public Utilities and Housing for Employees

Housing shortages and lack of public utilities can frequently result in heavy expense on the part of the railroad management because the men must live some distance from their point of work and are thus often unable to report on time. It is also desirable that employees live near the facility in order that they can be readily called in time of peak business or emergency.

(e) Distance from Industrial Area

Many of our large yards have been developed near areas where traffic originates or terminates. This is highly important in order that freight trains can be operated the maximum number of miles without reclassification. In congested industrial areas it is desirable to have classification yards near the source of traffic so that freight trains can be blocked to distant points and avoid the high cost of yarding these trains at intermediate points. Present labor contracts require separate crews to handle cars within yard limits, which increases cost whenever trains are yarded.

The speed of freight traffic is one of the most important features in the railroad transportation field. This speed can be increased if proper facilities are developed near large industrial areas that will allow the through movement of fast freight trains from one industrial area to another. Whenever freight trains are yarded there is a certain amount of time during which the traffic must stand still. When yard locations are selected that will result in the minimum number of stops for through freight trains the

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at points that will allow the maximum movement of the trains by any one crew in order to avoid the time lost when crews are changed at intermediate points. The rapid transition from steam to diesel power has increased freight train distances between stops and it is now feasible to run freight trains hundreds of miles without stopping to service any of the equipment. With this point in mind, yard locations should be selected that will give the maximum turn around efficiency of motivepower, as availability decreases on units used in short turn-around service.

2. Yards—Their Effect on the Economics of Location

(a) Real Estate Values in Industrial Areas

The desirability of having yards so located as to facilitate maximum operating efficiency usually demands a site where real estate values may be high. In heavily congested industrial sites property values may be high for some distance surrounding the area. This situation must be analyzed, as the advantages of such yards from an operating standpoint are materially reduced as the location of the yard is removed from the origin or destination of freight.

(b) Topography of Area for Potential Yard Location

The advantages to be gained in operating efficiently may determine desirable yard locations; however, the general topography of the area may be such as to prohibit its selection. This in turn often results in line changes or relocation in order to find a location for the yard that can be utilized to financial advantage.

3. Yard Location as Determined by Local Production and Destination of Freight

The yards should be located so that traffic moves into them in its normal route from the point of origin. It is undesirable to move any freight traffic in the reverse of the normal direction. This should be considered where traffic originates and flows as a rule toward certain areas and, so far as possible, the yard should be located at some point through which the traffic will normally move enroute to destination. The same general scheme will apply at the destination of the freight, as trains must be broken down by delivering lines and destination areas.

Conclusion

The following points should be considered in locating a yard.

1. Yard terrain.
2. Adequate size.
3. Labor availability.
4. Availability of public utilities and housing.
5. Distance from industrial area.
6. Distance from seaport or inland port.
7. Location at junction points of main lines or interchange points.
8. Sufficient area to expand.
9. Switching limits.
10. Distance between yards to secure maximum efficiency of power and crews.
11. Real estate values in industrial areas.
12. Topography of area.
13. Yard location as determined by local production and destination of freight.

Report of Committee 13—Water Service and Sanitation

H. E. Silcox, *Chairman,*
R. C. Bardwell
I. C. Brown
R. W. Chorley
R. E. Coughlan
B. W. DeGeer
C. E. Fisher
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J. M. Short
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H. W. Van Hovenberg
R. E. Wachter
C. L. Waterbury
J. E. Wiggins, Jr.
E. L. E. Zahm

Committee

* Died May 26, 1949.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, presented as information .... page 126
2. Intercrystalline and other types of corrosion of steam boilers.
   No report.
3. Federal and state regulations pertaining to railway sanitation, collaborating with joint committee on railway sanitation, AAR.
   Progress report, presented as information .... page 127
4. Mechanics of foaming and carry-over in locomotive boilers.
   No report.
5. Sanitation practices for construction and operation of camp outfits.
   Final report, submitted as information .... page 127
6. New developments in water conditioning for diesel locomotive cooling systems.
   Progress report, offered as information .... page 134
7. Railway waste disposal.
   Progress report, submitted as information .... page 141
8. Inspection and maintenance of steel water tanks.
   Final report, offered as information .... page 147
9. Corrosion and incrustation in return systems.
   Final report, submitted as information .... page 150
10. Control of algae and plant growth in water storage reservoirs.
    Final report, submitted as information .... page 155

The Committee on Water Service and Sanitation,
H. E. Silcox, *Chairman.*

AREA Bulletin 483, November 1949.

Report on Assignment 3

Federal and State Regulations Pertaining to Railway Sanitation

Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), R. C. Bardwell, B. W. DeGeer, R. S. Glynn, S. H. Hailey, A. W. Johnson, H. F. King, G. E. Martin, G. F. Metzdorf, L. R. Morgan, A. B. Pierce, J. M. Short, D. C. Teal, R. E. Wachter.

This is a report of progress, presented as information.

Your committee reported last year that the Sanitation Research Project of the AAR expected to complete its present assignment, with a final report by September 30, 1949. It has not been possible to keep this schedule because of need for additional studies that required further research before well-founded conclusions could be drawn. It was found that more extensive testing of devices to control discharge of or to retain waste from passenger car toilets was desirable, particularly with respect to the sphincter valve which automatically withholds hopper discharges until predetermined train speeds have been reached.

The bacteriological samplings of ballast and of roadbed drainage required more time, as did the request of the Joint Committee on Railway Sanitation that the Research Project and the U. S. Public Health Service jointly make sanitary surveys of several coachyards and stations.

In the interim work is progressing on the completion of the several technical reports, and it is now expected that the field and laboratory experimentation will be completed prior to December 31, 1949, and that the final report will be available prior to June 30, 1950. Representatives from the Engineering Division on the Joint Committee on Railway Sanitation are R. C. Bardwell, A. B. Pierce and H. W. Van Hovenberg.

Report on Assignment 5

Sanitation Practices for Construction and Operation of Camp Outfits

D. C. Teal (chairman, subcommittee), A. K. Frost, H. E. Graham, H. F. King, L. R. Morgan, J. Y. Neal, A. R. Nichols, A. B. Pierce, E. R. Schlaf, H. M. Schudlich, J. W. Ussher, H. W. Van Hovenberg, C. L. Waterbury, E. L. E. Zahm.

This subject was assigned in 1947. The first report in 1948 consisted of a review of past practices and current developments. The second report in 1949 gave specific recommended practices to govern (1) Design and equipment and (2) Maintenance and operation of camp cars. This year's report, intended to be the final one, presents similar data for stationary or permanent type railway labor camps. Like the previous ones, it is submitted as information.

From questionnaire data furnished by the AREA membership, it is estimated that approximately 90,000 railway maintenance of way employees now live part time in railway labor camps. Of this number, possibly 30,000 are quartered in the permanent camps and the remainder in "floating" camp car outfits.

According to personal observation of your committee and a consensus of the questionnaire data, the sanitary conditions of most of the permanent type labor camps are

Kenneth Plummer Howe

Kenneth Plummer Howe, a member of the committee, died on May, 26 1949. He was born January 17, 1891 at Elizaville, Fleming County, Ky. His parents were Henry S. Howe and Lida Plummer Howe.

He was graduated from the University of Kentucky, College of Mechanical and Electrical Engineering, with a degree of B. S. M. E. in 1915 and was a member of Tau Beta Pi, an honorary engineering fraternity.

Upon graduation, he was employed by the Babcock and Wilcox Company of Barberton, Ohio, as draftsman and inspector of boiler tubes and munition steel until May 1917, at which time he entered the service of the Louisville & Nashville Railroad as draftsman in the chief engineer's office.

From April 1918 to December 1918, he was a second lieutenant, field artillery, U. S. Army.

Upon completion of his military duty, he returned to the Louisville & Nashville on January 1, 1919, as draftsman in the chief engineer's office. Subsequently, he was promoted to transitman and then to assistant engineer. On April 1, 1939, he was promoted to the position of assistant engineer, water supply, for the Louisville & Nashville, which position he held at the time of his death.

He was elected to membership in the AREA on March 6, 1946, at which time he also became a valued member of Committee 13—Water Service and Sanitation. His untimely death is regretted by his committee and by his friends in this Association.

Mr. Howe married Annie Laurie Hughes in 1928. Mrs. Howe and their two children, Emi-Lee Howe and Kenneth Plummer Howe, Jr., survive Mr. Howe.

Report on Assignment 1

Revision of Manual

G. E. Martin (chairman, subcommittee), R. C. Bardwell, R. E. Coughlan, B. W. DeGeer, E. M. Grime, T. W Hislop, Jr., H. F. King, H. L. McMullin, G. F. Metzdorf, Theodore Morris, J. Y. Neal, D. C. Teal, T. A. Tennyson, Jr., J. W. Ussher, R. E. Wachter, J. E. Wiggins, Jr.

Your committee considered revision of the Manual, pages 13–74 and 13–75, and collaborated with Committee 22 in connection with revision of Chapter 22 of the Manual, pages 22–10 to 22–14, Housing Maintenance of Way Employees.

After careful consideration it was the consensus that revisions should be deferred until after publication of the report on Assignment 5 of Committee 13 in order to have the benefits of any suggestions in that report for the revisions of these sections of the Manual.

No other revisions have been considered this year.

Special hand washing facilities should be provided in connection with and convenient to all food handling operations.

Ventilation.—Provide metal hoods over stoves and exhaust fan ventilator in addition to the natural ventilation through windows.

Tables and Shelves.—Fixtures used in preparation and serving of food or for storage of cooking utensils should have smooth, water resistant surfaces and be so constructed as to be easily cleaned.

Food Storage.—Provide clean, dry rooms with bins or shelves for storage of packaged and nonperishable foods, protected from rodents, insects, dust and other contaminating influences.

Refrigeration.—Install electric or ice refrigerators of adequate size and designed to store perishable foods at below 50-deg. F. temperatures, properly drained and constructed of materials and in such a manner that will permit thorough cleaning.

Dishwashing Equipment.—Kitchens should have two-compartment sinks of ample size and depth, constructed of rust-proof materials and a water heating arrangement that will provide an ample supply of hot water.

Water Supply Facilities

Source.—Every camp should have an adequate and convenient supply of water of a quality acceptable to the state board of health, preferably from a city water system. This supply is considered adequate if and when capable of delivering 35 gal. per person per day to the site at a rate 2½ times the average hourly demand. There should be but one source.

Distribution.—Piped distribution to buildings should be provided if at all possible. The distribution system should be capable of supplying water at normal operating pressures to all fixtures for simultaneous operation.

Protection Against Pollution.—When the drinking and wash water supply is taken from railway owned wells or springs, special precautions should be observed in the design and construction to prevent contamination at the source. Wells should be located, cased, topped and the pump attached so as to exclude surface waters. Springs should be completely covered and otherwise protected from airborne and surface drain water pollution. The distribution system should be designed so that the water remains enclosed in transit and can be drawn only from spigot outlets.

Drinking facilities should be of type acceptable to the public health authorities. Drinking fountains with angle jets are preferred.

Washing and bathing facilities should be provided and located convenient to sleeping and living quarters, preferably in the same building and in the following ratio:

One wash basin for every 5 men.
One shower head for every 10 men.
One laundry tray or tub for every 40 men.
One slop sink in each building.
Basins and sinks should have hard, smooth, rustproof surfaces.

Install a heater and piping system to deliver an adequate supply of hot and cold running water to the above fixtures.

As a matter of economy and convenience, bathing facilities are often placed in the same room or adjacent to flush type toilets. There is no objection to this from a sanitary viewpoint, but if in same room, the toilets should be partitioned off for privacy.

fair to good. Being usually located in or near cities, they frequently have access to approved drinking water supplies and to sanitary sewers. Their construction is in most cases handled by professional designers of the chief engineer's office who are familiar with local and state sanitary requirements; also, the fixed camps are apt to receive more attention from supervisory officers than the floating camp car outfits.

Your committee has prepared and presents herewith recommended sanitation practices for (1) Design and construction and (2) Maintenance and operation of stationary railway labor camps. These were derived in part from a study of past and present practices and from a review of all federal and state health service regulations pertaining to camp sanitation that could be found.

1. Recommended Sanitation Practices for the Design and Construction of Stationary Railway Labor Camps

Location and Layout

Environmental.—The site should be of adequate size and if possible on high, well drained, grassy ground, removed from swamps and from city or industrial waste dumps. Construction of the camp should include the grading and ditching necessary to eliminate casual standing water, also the seeding of barren ground with grass where consistent.

Layout.—Sleeping and living quarters should be separated from kitchen and dining room facilities and in separate buildings when practical. Walks should be provided between buildings.

Sleeping and Living Quarters

General.—Buildings should be designed in accordance with local and state building codes. Exterior walls, floors and roofs should be insulated and otherwise constructed in a substantial manner so as to provide adequate protection for occupants against the elements.

Space Requirements.—Fifty square feet of floor area should be allowed per person in sleeping quarters. The minimum ceiling height should be 7 ft. 6 in.

Floors.—Floor surfaces should be smooth, water resistant and easily cleaned. Wooden floors should be elevated at least one foot above ground level to permit circulation of air beneath.

Walls and ceilings should have a smooth washable surface with as few cracks as possible to minimize harbouring of insects. They should be finished in light colors.

Heating facilities should be designed to provide comfortable (72-deg. temperature) living conditions in the coldest weather.

Ventilation.—Provide window openings totaling at least 12 percent of the floor area, one-half of which should be constructed that they may be opened for ventilation.

Screening.—Install screens on windows used for ventilation and self-closing screen doors to open outward. Use 16-mesh screening or finer.

Lighting.—Adequate artificial lighting, preferably electric, should be provided where needed.

Lockers.—Each occupant should have a clothes locker of adequate size preferably of steel construction.

Kitchens and Mess Halls

General.—Most of the recommendations regarding design and construction of sleeping and living quarters apply here with the following additions:

Trash Disposal.—Provide an incinerator or trash burner for each camp, located on the prevailing down-wind side of camp if possible and at least 300 ft. from occupied quarters.

2. Recommended Sanitation Practices For the Maintenance and Operation of Stationary Railway Labor Camps

Responsibility

Foremen.—The foreman in charge should be directly responsible for the sanitary conditions of his camp.

Division Engineers.—The division engineer and his supervisory staff should exercise control over sanitation in the labor camps under their jurisdiction.

The chief engineering officer and the departmental heads concerned, should also assume supervisory control over sanitary conditions of labor camps.

Sanitary Inspections

Official sanitary inspections should be made weekly by the foreman in charge and by his superior officer whenever he visits the camp.

Personnel For Sanitary Work

Small Camps.—For camps occupied by from 10 to 40 people, one man should be assigned on a part-time basis to do the cleaning work necessary for maintenance of proper sanitation in sleeping and living quarters. The amount of time spent should be at the judgment of the foreman.

Large Camps.—Of over 40 people should have one or more men assigned full time to housekeeping duties. These men should be capable and show concern about their work.

In Kitchen and Mess Hall.—Cooks and their helpers should do the cleaning work within their province.

Sanitary Supplies and Repairs

Supplies should be ordered through established channels.

Minor Repairs.—Repairs to screening, plumbing, etc., whenever possible should be done by camp personnel.

Major repairs should be handled by the division engineer or the general officer in charge.

Sickness and Disease

Sick employees should be treated by a doctor as soon as possible, preferably by the nearest company doctor. In case of a communicable disease, the doctor will direct quarantine or fumigation procedure.

Cooks and Food Handlers

Physical Requirements.—Cooks and food handlers should be in good health, free of skin rashes, clean of person and should wear clean clothing. They should keep finger nails cut short and hair trimmed.

Examination and Certification.—Cooks and their helpers should be required to take a special physical examination by a company doctor on entering service and at six months' intervals thereafter. The written certificate of good health should be kept on file in the camp. No diseased person should be allowed to cook or serve food.

Bath rooms, whether inside or in a separate outside building, should be well lighted and ventilated. Floors should be constructed of concrete or better composition with a smooth finish (but not slippery) and sloped to drain. Provide floor drains for shower stalls and otherwise where needed. The walls should be smooth and washable.

Toilet Facilities

General.—Toilet facilities, preferably flush type, should be provided in ratio of one water closet or seat for every 12 men and one urinal for every 20. These should be located convenient to living quarters, in the same building when possible and in no case more than 200 ft. away. Equipment, design and construction must be in accordance with local and state codes. Rooms should be large enough and should have adequate ventilation and artificial lighting. All openings to the outside should be securely screened.

Sewage Disposal

In Urban Areas.—Local and state sanitary codes usually require that sewer connections be made to existing city lines if at all possible, otherwise that septic tanks be installed.

In Rural Areas.—Pit privies, properly constructed and maintained will comply with most state health laws, however, the public health services urge and it is recommended that septic tanks be installed for permanent labor camps housing more than 15 men, regardless of whether located in city or in country.

Pit Privies.—If used, should be located, constructed and maintained in accordance with local state health recommendations so they will not cause contamination of any water supply, attract and breed flies or vermin, or produce unpleasant odors. They should be at least 200 ft. from the kitchen or mess hall, drinking water wells or streams. In erection, it is important that the pit be deep enough and that tight conact be made between box and ground to prevent entry of flies.

Drainage Facilities

General.—Properly trapped drain lines should be provided to carry away the waste water from bath rooms, laundry tubs, kitchen sinks, etc. Whenever possible, connect these drains to existing city sewers, otherwise to the special camp sewage disposal facilities. Install grease interceptors on waste water drains that empty into a septic tank disposal system.

Equipment For Collection of Garbage and Refuse

General.—These facilities should be included in the original design as they are an important factor in maintenance of sanitation.

Garbage Cans.—A sufficient number of water-tight metal cans with tight fitting lids should be placed in or near kitchens and mess halls for the collection of garbage.

Garbage Stands.—A concrete platform should be installed near the kitchen for storage of full cans awaiting pick up. Provide drain for, and a curb around this platform so it can be washed down.

Can Washing Facilities.—A hot water tap or cold water and steam connections and a hose should be provided for washing cans, either at the storage platform or at the place cans are emptied.

Trash Cans.—At least one metal can with fly-tight lid should be placed on a wood or concrete stand, convenient to each occupied building for the collection of combustible waste.

Drinking Water

If From a Private Source.—Water should be routinley tested for its bacteriological quality and if necessary, arrangements made to have it chlorinated to a 0.5 ppm. residual 30 min. before being used for drinking.

Containers.—If for one reason or another containers are used for collection, storage and distribution of drinking water, they should be of rustproof materials and designed to protect the contents from contamination. In general, they should have large filling openings with tight overlapping lids and a covered spout or recessed spigot outlet depending on usage. The dispensing containers should be constructed so that water can be drawn only from the spigot. All drinking water containers should be labeled "For Drinking Water Only."

Drinking Cups.—The use of paper cups should be encouraged where there are no drinking fountains and when otherwise practical. If used, dispenser must be provided and arrangements made for collection and disposal.

Sanitary Care of Equipment..—When containers are used for handling and storage of drinking water, they should be kept clean and sterile by washing and rinsing in boiling hot water at weekly intervals. Care should be taken to prevent contamination in handling. Containers used for transporting drinking water should be rinsed with pure water before each filling and the lids should be kept closed.

Ice.—When added direct to water for cooling, ice should first be washed with pure water and otherwise handled with clean hands and in a sanitary manner.

Care of Toilets and Privies

Flush type toilets and urinals should be inspected daily to ascertain whether they are working properly. Scrub floors and fixtures semi-weekly with soap and water. Keep supplied with toilet paper.

Pit Privies.—The seats should be washed semi-weekly with soap and water and the inside of the building sprayed monthly with a residual DDT solution to control flies. If odors become obnoxious, spray contents and sides of pit as often as required with a two percent cresol solution or some other disinfectant-deodorant. When filled to within two feet of the top, pits should be closed by filling with earth and the building set up over a new pit.

Insect and Rodent Control

General.—Labor camps are more or less afflicted with pest insects and rodents of various kinds, the most common being bed bugs, roaches, mice, body and head lice, mosquitoes and flies. Simple cleanliness, frequent and abundant use of soap and water, and sanitary disposal of wastes are the first essentials of control. When for one reason or another, insects become prevalent, the following additional measures should be taken:

Screening.—See that screens are in good repair and screen doors kept closed.

Spraying.—Spray the infested and affected quarters periodically with DDT and/or pyrethrum type insecticides.

Repellents.—Provide a good insect repellent for the use of employees required to work in heavily infested areas outside the camp.

Rodent Baits.—Set out poison baits and traps for mice and rodents.

Supervision of Control Work.—The proper application of insecticides and rodent baits requires certain knowledge and should be performed by instructed personnel. Railroads having extensive insect control work to do should designate either system or division men to organize and supervise this work. The technique of spraying, description of equipment required, etc., are outlined in many trade and public health service publications.

Environmental Sanitation

General.—The grounds and open areas surrounding the camp should be maintained in a clean and sanitary condition free from rubbish, waste papers and garbage.

Sanitation in Sleeping and Living Quarters

Cleaning.—Floors should be cleaned daily by appropriate methods, and all trash collected and burned.

Heating and Ventilation.—Healthful living conditions should be maintained by proper attention to heating and ventilation.

Beds should be made up after each use, by the occupant.

Bedding.—Blankets and comforts should be aired and sunned semimonthly. Linens, when used should be changed at least twice each month.

Sanitation in Kitchen and Mess Hall

Cleaning.—Floors should be scrubbed daily with warm water and soap, tables and shelves washed daily, lower part of walls washed weekly and food storage rooms and containers cleaned by appropriate methods at weekly intervals.

The kitchen and mess halls should be kept free of dirt, dust, rubbish, roaches, ants, mice and flying insects.

Dish Washing.—The minimum dish washing procedure should be:

(a) Scrub in hot (130-deg. F.) soapy water in one sink.

(b) Rinse and sterilize by submersion in extremely hot (180-deg. F. or more) water for at least two minutes in another sink. Use a wire basket for this purpose.

(c) Air dry.

(d) If necessary to use drying towels on glass ware and cutlery, it should be done with a clean towel. After use, towels should be boiled in soapy water, then thoroughly rinsed and dried, preferably in the sun. Dish towels should be used for no other purpose.

Broken or cracked dishes should not be used.

Garbage Disposal

Garbage should be handled in such a way as to not attract flies nor to otherwise create a nuisance or menace to health. It should be collected in water-tight metal cans with tight lids and disposed of daily. Arrangements for pick up by city or private garbage collector should be made when possible, otherwise, all garbage, including empty food cans should be buried at an appropriate location (at least 300 ft. from any occupied building), on company owned property. Pits for this should be dug deep enough to allow two ft. of backfill over garbage. The backfilling must be done immediately to minimize fly attraction and breeding.

Garbage cans should be kept clean on the outside and covered. They should be washed with hot water or steamed inside and out every time emptied. The rack or platform on which cans are stored should be washed down daily.

Rubbish.—Old papers, boxes and empty food containers should be collected daily and burned in the camp incinerator.

At the time those recommendations were made, no data were available on the use of waters for cooling systems of higher than 23.2 gr. per gal. TDS and very meager data on waters containing appreciable amounts of hardness.

Reports recently received indicate waters have been successfully inhibited containing up to 50 gr. per gal per TDS and 10 gr. per gal. hardness if the chloride content of the water were low, i.e., 1 gr. per gal. in systems containing certain aluminum composition alloys and not more than 4 gr. per gal. in systems without aluminum.

Most railroads will at one time or another experience loss of cooling water on some units to the extent that make-up water may be as great as 25 percent of cooling system capacity per day. It is the opinion of your committee that the water quality requirements should be sufficiently restrictive so that such a situation can be tolerated until repairs can be made without severely damaging the engines.

A number of recommendations have been made by various engine builders and chemical companies governing water quality and chromate concentration to be used for cooling water treatments.

Some of these recommendations are tabulated in the table.

RECOMMENDATIONS FOR DIESEL COOLING SYSTEM WATER TREATMENT

Source	*Initial Water*	*Quality*	*Quality of Water in Cooling Systems*			
			Hd	*TDS*	*pH*	*Na^2CRO^4*
AREA Proceedings Vol. 48–1946	0.0	1.0 gpg.	0.5 gpg.	23.5 gpg.	8.5–9.0	1½ lb. sodium chromate per 100 gal.–1795 ppm.
Locomotive Co. "A"	"Use clean water only"	--------	Not stated	----------	8.5 min.	2000 ppm. min.
Locomotive Co. "B"	"Distilled water or equivalent"	--------	Not stated	----------	9.7 max.	1710 ppm. min.
Locomotive Co. "C"	Not stated	--------	Not stated	----------	7.5–8.5	154–205 ppm.
Chemical Co. "A"	Not stated	--------	Not stated	----------	8.9–9.1	40 oz./100 gal. Formula 38 at 72% CrO^4–2350 ppm.
Chemical Co. "B"	Not stated "Dist. water or equivalent ideal"	--------	Not stated	----------	8.5–9.7	1710–2187 ppm. 3 lb. of Formula 517 per 100 gal.
Chemical Co. "C"	Not stated	--------	Not stated	----------	7.5–9.5	500 ppm.

In general it is not believed to be practical for most railroads to use different water standards for each different make of locomotive since frequently several makes of locomotives are serviced at the same terminal. The need for a set of standards universally satisfactory is therefore clearly indicated.

In order to maintain the selected standards, control must be established which will assure that they are maintained. Too much emphasis cannot be placed upon the need for control of inhibitor concentration, particularly when severe water leaks are experienced.

Fig. 1 illustrates the corrosion that can occur in a relatively short time. The corrosion shown occurred in a 30-day period on a severely leaking engine. During this

Summary

The basic rules of sanitation for railway labor camps should be that camps be so constructed, maintained and operated as to provide healthful living conditions for the occupants and not endanger the health of the public.

References

The following public health service publications are cited:

Maryland, State Department of Health.—Regulations governing camp ground sanitation. Criteria for shelter and sanitation—Housing for seasonal agriculture workers.

South Carolina, State Board of Health.—Rules and regulations on construction camps.

North Carolina, State Board of Health.—Suggested rules and regulations governing the sanitation and operation of trailers and trailer camps.

West Virginia, State Health Department.—Regulations governing the sanitation of labor and industrial camps.

Arizona, State Department of Health.—Sanitary Code—Rules and Regulations.

Illinois, State Department of Public Health.—Rules and regulations for the sanitary control of tourist camps. (Educational Health Circular No. 99).

New York, State Department of Health.—Reprint of Annual Report 1944, Division of Sanitation.

Indiana, State Board of Health.—Public Health Regulations HSE 17 and HFD 17.

U. S. Department of Labor.—Migrant labor, a human problem. Report and Recommendations, Federal Interagency Committee on Migrant Labor.

Harvest Nomads, Bulletin No. 73, Division of Labor Standards.

U. S. Public Health Service—Sanitary Engineering Division.—Circular on Use of DDT—Interstate Carriers, Land and Air. Public Health Bulletin No. 280, Ordinance and Code Regulating Eating and Drinking Establishments.

U. S. Army.—Dunham's Military Preventive Medicine.

Report on Assignment 6

New Developments in Water Conditioning for Diesel Cooling Systems and Steam Generators

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This report of progress is offered as information.

Diesel Cooling Systems

It is believed that the railroads which have followed the previous recommendations of your committee, for the prevention of corrosion, scale and sludge in diesel locomotive cooling systems, have experienced very little, if any, difficulty with the locomotive cooling systems.

Additional experience has indicated that the previous recommendation, as found in AREA Proceedings, Vol. 48, 1947, pages 209–210, are somewhat more restrictive than necessary with respect to the acceptable amount of TDS,* hardness and pH range.

* Total dissolved solids.

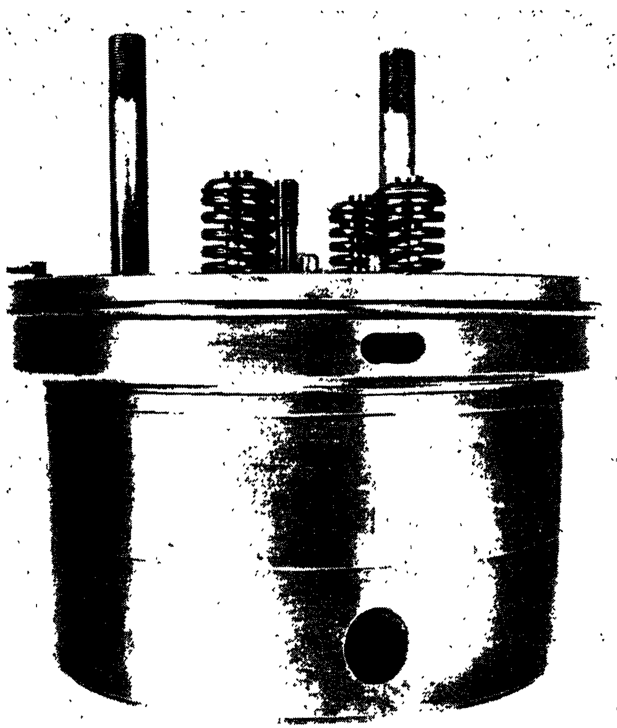

Fig. 3.—Cylinder Head Removed after 80,000 Miles in Freight Service. Compare with Fig. 1 and note absence of Scale or Corrosion.

30-day period the cooling water was tested 16 times. Eleven times the concentration of inhibitor was found to be so low that it was necessary to add a total of 56 lb. of inhibitor. In five of the instances the addition of a complete charge of inhibitor was required. Under these circumstances, control at every division point becomes a necessity.

It is believed that the most effective control can be exercised by the terminal forces under the supervision of the railroad's water chemist.

It has been found that the pH of the cooling water after the addition of the corrosion inhibitor is only slightly dependent upon the initial pH of the water and almost completely dependent upon the balance of the alkaline and chromate materials in the inhibitor. Therefore after a proper balance has been secured the pH value of the cooling water will fall in the predetermined range if the chromate concentration is correct. Thus an analysis for the chromate concentration is all that is required for routine control.

The most commonly used analytical control methods are as follows:

1. Colormetric standards for visual comparison.
2. Electric conductivity.
3. Photometric using 1 cc. cooling water diluted with 10 cc. distilled water adding 2 cc. dilute H_2SO_4 (1 — 10) and 2 cc. 7.5 percent solution KI.

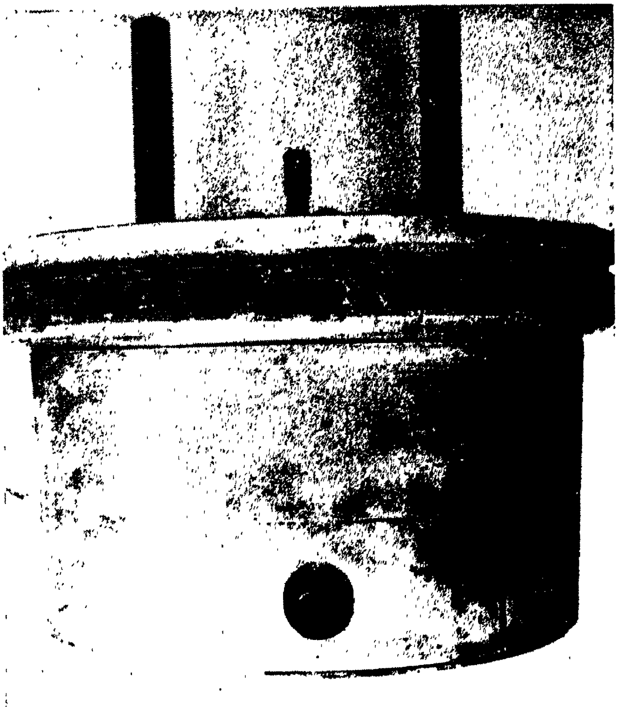

Fig. 1.—Cylinder Head Showing Corrosion at the Seal Ring Area.

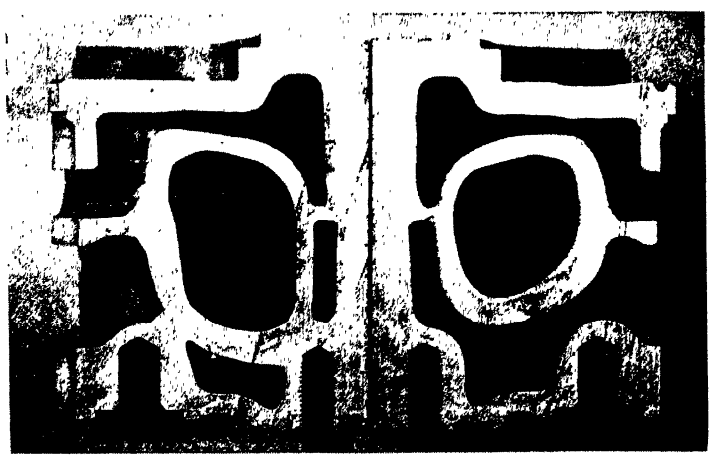

Fig. 2.—Sectioned Cylinder Head Removed after 250,000 Miles in Freight Service. Water Passages Completely Free from Scale or Corrosion.

4. Chemically impregnated blotter to give a colored spot compared with a permanent color standard.

Methods 2 and 4 are believed to be the most satisfactory for the terminal forces. Method 1 is quite inaccurate in the range of chromate concentration most commonly used. Method 3 is accurate but most adaptable for use in the laboratory.

The pH determinations should be made in the laboratory as required. A standard electric pH instrument is the most satisfactory.

A number of diesel engine cooling system specimens have been secured and photographed whose histories are known. The cooling waters used were typical midwestern waters ranging in hardness from 1 gr. per gal. up to 10 gr. per gal. and with TDS up to 25 gr. per gal. None of the water supplies exceeded 2 gr. per gal. chloride content.

Alkaline chromate inhibitors were used in quantities to maintain a concentration of sodium chromate of 1½ lb. per 100 gal. and a pH value of 8.5 to 9.5. Cooling system samples were analyzed at each terminal servicing and additional inhibitor added as required.

Figs. 2, 3 and 4 indicate waters of appreciable TDS and hardness can be successfully inhibited against corrosion.

Waters with a TDS up to 50 gr. per gal. are being successfully inhibited when the chloride contents are low. There are very few data on the use of waters of higher TDS content.

Waters which contain appreciable suspended solids tend to lodge sludge in the low velocity areas. These sludge deposits are almost impossible to remove by flushing. Corrosion can more readily occur under a sludge deposit than upon a clean surface. A maximum limit of 1 gr. per gal. is indicated for good results.

The hardness which can be tolerated without excessive scale or sludge formation is to a considerable extent dependent upon the amount of make-up water required. This is in turn primarily dependent upon the loss due to leaks and the maintenance practices used for assembly renewals. For most railroads it is not believed water with a hardness greater than 7 gr. per gal. can be used without some degree of trouble.

Low chloride content reduces the tendency of the water to corrode. Waters with more than 1 gr. per gal. chloride probably cannot be completely inhibited for aluminum corrosion. Waters containing more than 4 gr. per gal. chloride cannot be completely inhibited against iron or steel corrosion without excessively high chromate content.[1] The attack experienced with partial inhibition is apt to be dangerous localized corrosion.

A number of instances of cooling system corrosion have been noted when alkaline chromate corrosion inhibitors have been used in what is believed to be adequate concentration but with the pH range of 7.0 to 7.5. None has been noted when the pH was 8.5–9.5. The experience with a pH above 9.5 is quite limited. Some reports have been received of a tendency to corrode certain composition brass parts at pH values of 10 and above. The pH value of the cooling system is lowered at times by leakage of blow-by gases into the cooling system. This is a most undesirable condition and requires early correction to prevent corrosion from occurring.

The exact minimum amount of chromate which will afford complete protection to an engine appears to be somewhat greater than that which might be required in a less complex structure. In small water interstices the problem of replacement of the expended chromate is rather severe due to the lack of circulation. It therefore is advantageous to have a relatively high concentration in the body of the system to take maximum advantage of even the slightest circulation.

The minimum concentration is also governed by the amount of chlorides present.

[1] M. Pourbaux "Corrosion," Vol. 5, No. 4, April 1949, page 132.

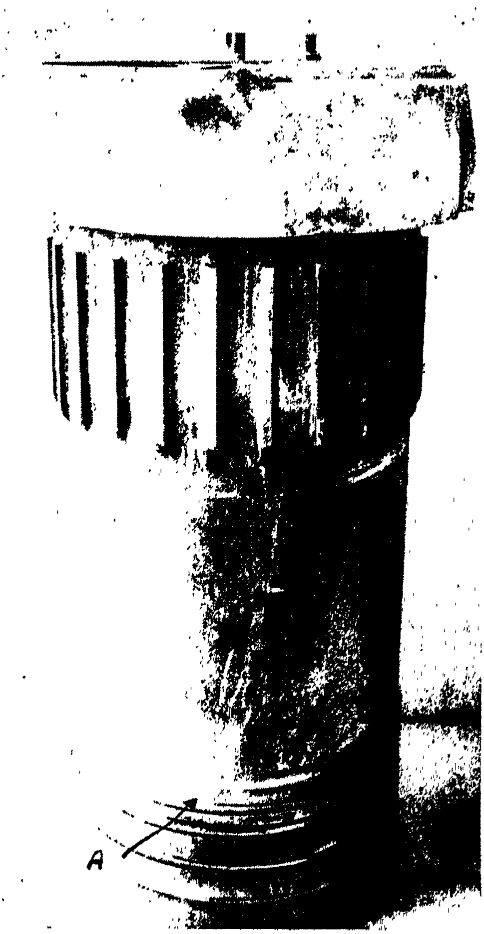

Fig. 4.—Cylinder Liner Removed after 250,000 Miles in Freight Service.

Arrow A indicates location of the inlet port. The inlet port and cast ribs are the two locations most subject to corrosion. This liner is in "new" condition on the water side.

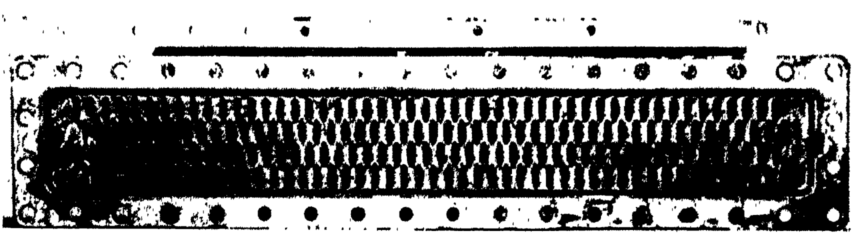

Fig. 5.—Inlet End, Water Side of Oil Cooler Removed after 228,000 Miles of Freight Service. It is Free From Either Scale or Corrosion.

Steam Generators

Reports are being received concerning foaming on the superheater type generators. There seems to be some variation in the concentration of dissolved salts at which foaming will occur, but it appears to be in the range of 350 to 450 gr. per gal. on various water supplies at maximum steam demand.

This indicates the need for setting up of blow-off schedules which will keep the boiler water concentration below the foaming point.

If the conservation of water is sufficiently important or the required blowing cannot be done the use of anti-foam will be required.

When foaming does occur the steam generator will shut itself down. Therefore foaming cannot be tolerated, particularly if the steam demand is heavy. This is the operating condition when foaming is most likely to occur.

Where amine type anti-foam compounds are being used, concentrations up to 950 gr. per gal. are being carried without foaming occurring. This reduces the required blowing to such a degree that little if any foaming trouble should be experienced except with very poor waters.

Report on Assignment 7

Railway Waste Disposal

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This is a progress report and is offered as information.

A previous report of your committee outlined the railway waste disposal problem in connection with those materials which would likely be involved in water pollution, both from past railway experience and the trend of possible future legislative action.[1] Although it was pointed out that waste disposal practices, properly carried out, can often pay for themselves in recovery of valuable materials, this possibility alone will not always motivate abatement of stream pollution in which industry is involved. The carrying out of waste disposal through waste treatment facilities is very often just an added operating expense. When this is the case it is logical that any industry will do only those things required by law to produce satisfactory stream conditions in the eyes of the regulatory bodies concerned.

With the passing of the Water Pollution Control Act by Congress, and introduction of additional bills along this line, the machinery has been set up whereby state and federal governments can study the waste disposal problems and order abatement of pollution on a legal basis with the assistance of the federal courts. Since the regulations set up by law will, in many cases, determine the extent of waste treatment, then the laws are actually the guide for both industrial and railway waste disposal. Your committee has circulated a questionnaire among state health officials to determine the status of regulations, and to enable it to give a summary appraisal of the legal basis for waste disposal practices at the present time, with some predictions as to the future. Replies were received from 44 of the states contacted, many of which contained copies of the laws and regulations and were quite complete.

[1] AREA Proceedings, Vol. 50, 1948, page 186.

With as little as 1.9 gr. per gal. chloride as sodium chloride present, from 58.3 gr. per gal. to 100 gr. per gal. potassium chromate is required to give complete inhibition in an unbuffered solution.

The presence of substances such as sodium bicarbonate or carbonate permit the lowering of this critical value.[2]

In view of the relatively heavy dosage known to be required for perfect inhibition, a dosage well above the known minimum requirement is indicated. The suggested minimum dosage is at least 105 gr. per gal. of chromate as sodium chromate.

As far as is known no adverse effects will be experienced from much higher chromate concentrations.

In view of the additional experience which has been gained, the following recommendations are made as a guide in the selection and treatment of waters to be used in diesel cooling systems.

1. Use only clear waters with 1 gr. per gal. or less of suspended solids.
2. A maximum limit of 50 gr. per gal. TDS exclusive of the corrosion inhibitor.
3. A maximum limit of 1 gr. per gal. of chlorides if aluminum corrosion is of concern, otherwise 4 gr. per gal.
4. Pretreat to reduce the hardness to a maximum of 7 gr. per gal. if the raw water exceeds this amount.
5. Aftertreat the make-up water to maintain a minimum concentration of 105 gr. per gal. chromate as sodium chromate with a pH of 8.5-9.5.
6. Analysis as frequently as necessary to make certain these standards are maintained. On units in road service, when inhibitor is added by hand dosing, daily analysis will be required on most railroads.
7. Inspect the cooling systems at overhaul periods to insure the desired results are accomplished.

The use of cooling water treating plants at the watering stations will greatly simplify the problem of control since most of the replacement water used will be properly treated. More uniform results can be expected by this method of feeding than can be hoped for by hand dosing. A number of such installations have been made which are working successfully. Undoubtedly more installations will be made as the number of units in service increase. The installation of additional plants is indicated.

If water of suitable quality properly treated is kept in the cooling systems there should be no reason for draining the system except as required by maintenance or by mechanical failure. Periodic draining is not required.

Not infrequently a cooling system becomes contaminated by oil from a leak in the lubricating system or exhaust gas leaks into the cooling system. The efficiency of the cooling system can be reduced by oil contamination to the extent that adequate cooling cannot be secured.

The most common method of cleaning such a contaminated system is as follows:

1. Drain system while hot.
2. Refill with warm water, adding one ounce per gallon of an alkaline, oil emulsifying cleaner. Use an aluminum inhibited cleaner if aluminum is incorporated in the system.
3. Run engine until water reaches 150-deg. F. and for at least 30 min.
4. Drain and flush with clean warm water.
5. Refill with water containing the required corrosion inhibitor.

[2] Ibid.

require pretreatment of all wastes before discharge to bodies of water and this must be of the extent to render the wastes harmless. Since the streams of this country vary widely in quality due to long past uses and due to the fact that some of them have been and must be primarily channels for waste disposal, it was logical to set up waste disposal regulations on the basis of establishment of stream zones based on the use of the streams and whether it is possible and practicable to reclaim them or keep them in good condition. After a study of the reports it is evident that the trend in the states is to set up zones on their streams which will automatically determine the type of waste material they will stand and the amount of treatment which will be necessary. Use of the stream or body of water as public water supply rates as the highest use in most of the state and interstate schemes. Since the law of one state gives more detail in regard to quality limits in the stream zones, these regulations will be used as a general example of requirements of present and future stream zones. Some states use more classifications and some less, but the general plan is similiar. In this state, streams are zoned and classified according to their uses and Classes AA, A, and B can serve as sources of public water supply and as fish habitat in decreasing excellence. The following limits are given.

	Excellent Class AA	*Good Class A*	*Poor Class B*
MPN Coliform per 100 ml.			
Average any month	100 Max.	2000 Max.	10,000 Max.
Dissolved oxygen, ppm.			
Month average	7.5 Min.	6.0 Min.	5.0 Min.
Daily	6.5 Min.	5.0 Min.	3.0 Min.
5 Day B.O.D., ppm.			
Monthly average	0.75 Max.	2.5 Max.	6.0 Max.
Any day	1.0 Max.	3.5 Max.	7.0 Max.
Ph average any month	6.2 to 8.4	5.8 to 9.0	3.8–5.8; 9.0–10
Fluorides, ppm.	1.0 Max.	1.0 Max.	1.0 Max.
Chlorides, ppm. any day	50 Max.	250 Max.	500 Max.
Phenolic compounds, ppb.	None	5 Max.	25 Max.
Iron and manganese, ppm.	0.3 Max.	1.0 Max.	15 Max.
Color	20 Max.	75 Max.	150 Max.
Turbidity, except as result of heavy rain	10 Max.	250 Max.	No Standard
Industrial or domestic sludge deposits	None	None	Slight to moderate localized

In addition to the above standards these three classes of streams must contain no toxic substances, oils, tars, or free mineral acidity at any time, no floating solids or debris except from natural sources, and only slight amounts of taste and odor producing substances occasionally. Class C waters are those that are not satisfactory as a source of public water supply, unsuitable for fish habitat and recreational water, and to be used only as waste dumping places provided the public health is not endangered.

Wyoming laws state that railroads, etc., must not be built on water sheds of public water supplies unless the state board of health has been satisfied that waste disposal will be adequate. Oregon law restricts railroads, etc., from dumping wood and its products including sawdust, oil and related products, coal tar, creosote, etc., into the waters of the state. Other state laws call for no new sources of pollution either from new industries or changes in old ones, but all indicate a similar trend.

Of the agencies reporting, only Idaho. Louisianna and Nevada stated that they do not require that plans for waste disposal be submitted for approval by the regulatory body. Rhode Island requires that plans for treatment plants be submitted if they are

The Federal Law

Public Law 845, called the Water Pollution Control Act, in its present form, gives state agencies the initiative in solving their own problems by encouraging the enactment of uniform state laws, giving technical advice and assistance, and finally by legal action. In this final action the federal security administrator may, with the consent of the state agencies involved, request the attorney general to bring suit on behalf of the United States to secure correction. Although this law deals primarily with interstate waters, the United States government can recommend action even in the case of small streams or ditches which are carrying polluting material to interstate waters.

The "Navigable Waters Pollution Act," proposed in the 81st Congress as H.R. 4825, is a bill to somewhat modify the old Oil Pollution Act of 1924 which gives the secretary of war authority to order abatement of pollution of coastal and navigable waters by the discharge of oil from vessels. This proposed bill includes industrial wastes in general and in addition to vessels, names shore installations such as wharves, manufacturing establishments, and mills of all kinds. It is declared unlawful either to place the polluting material directly into a body of water or to place it on the bank of a body of water where rains, tides, etc., may wash it into the water.[3] The very different position of the government in Public Law 845 and H. R. 4825 is evident.

The State Laws

At the present time there are six states which do not have any formal water pollution control laws, but four of these either have legislation in progress or have committees active in accumulating data necessary for the formulation of laws. Without the formal pollution law, however, there is in the common law enough to make it possible to defend the inherent rights of the public in stream pollution. It has long been recognized that riparian proprietors are entitled to have streams come to them with their quality and quantity reasonably undiminished. Such reasoning forms the basis for the pollution control laws now in use.

Administration of the state pollution control laws is wholly or partly a function of the health department. In several states special water pollution control boards have been formed and these either report to the department of health or closely cooperate with it. The health officer is often a member of any special water pollution control body. The administration of the regulations set up by such a body is partly in the hands of the game and fish commission, conservation commission, etc., in some of the states. Any railroad officer desiring information concerning pollution regulations in a given state can be reasonably correct in making contact with the state health department.

The state pollution control laws, at present, are general in their statements and their primary function is to give authority for the creation of a regulatory body whose duty it is to set up the regulations to control water pollution. Sewage, which has been under regulation for a long time in most states, is usually mentioned separately from industrial wastes. The minimum treatment for sewage is based on what is necessary to protect the public health and usually consists of at least sedimentation with sterilization in some form. In one way or another the laws state that wastes must be kept out of public waters if they contain materials which may be harmful to the public health, deleterious to fish and other aquatic life, or if they would render the water otherwise unfit for its normal domestic, industrial or recreational uses.

Minimum treatment required for any industrial waste material depends upon its type and volume and its effect on the normal uses of the stream receiving it. Ten states

[3] Chemical & Engineering News, August 1, 1949.

Pennsylvania and New Jersey in 1936 and it aims to coordinate enactment of uniform laws and practices and to develop and propose objectives while the states act as enforcement agencies. This compact bases requirements on stream zones and four zones are set up.

3. The Interstate Commission on the Potomac River Basin was formed in 1941 by Maryland, West Virginia, Virginia, Pennsylvania and the District of Columbia to act as an advisory group to promote unform laws and practices, and to investigate and summarize technical data.

4. The New England Interstate Water Pollution Control Commission was signed in 1947 by Connecticut, Rhode Island and Massachusetts. This commission will work on water standards, advise, and classify streams, while the states will enforce the regulations set up.

5. The Ohio River Valley Sanitation Commission was made effective in 1948 with Indiana, West Virginia, Pennsylvania, Illinois, New York, Ohio, Kentucky and Virginia as members. Other states have been invited to participate. This commission will issue orders regulating pollution, and at the present, the minimum treatment is the removal of not less that 45 percent of the suspended solids.

Position of the Railroads

Replies received from 13 of the reporting states did not give any examples of railway wastes which would come under their industrial waste regulations. Several of these stated that there had not been sufficient study on this problem to make comment. Replies from other states cited types of wastes which had been troublesome and several of them named particular railroad facilities involved. These are summarized in Tables 1 and 2 which follow. While most of the states do not name any specific cases in which it has been necessary to order abatement of pollution from wastes from railway property, enough instances are cited to establish a trend and to serve as information as to where possible future action is likely to occur.

Indiana reported an example where a railroad has built pretreatment facilities for car washing wastes to prepare these wastes for disposal into a city sewer system.

Michigan has ordered abatement in cases of wastes from roundhouses and car washing facilities at Bay City, Niles and Battle Creek.

Pennsylvania has ordered abatement in one case of oil drainage from railroad classification yards at Harrisburg.

One large railroad system reports that an order was recently received from a stream pollution authority to discontinue discharge of oily wastes from an engine terminal to a river. In order to do so it was necessary to make changes in the sewer system at the engine terminal so as to separate the oil waste sewer pipe from the sanitary and storm water sewer pipes. The oil waste was passed through a diversion chamber into a large oil separator and sedimentation chamber. After the oil was skimmed the effluent was sent forward for discharge into the river. The normal sewage was passed through a large septic tank and then processed through an adequate disposal field. The whole project is working to the satisfaction of all concerned.

This study of current state regulations has not brought to light any new waste material from railway operation which was not reported in the previous study by your committee but has shown that these are of legal importance and, as a summary, the items to be considered are:

1. Oil, creosote, and their related products must be kept out of public waters. There appear to be no maximum permissible legal limits.

ordered built. Otherwise it was found that state regulatory bodies require that plans for waste disposal be submitted, most of them prior to construction, for approval. Permits are then issued containing the conditions relevant to the case. Maryland and Iowa, as examples, require prior approval of plans for new facilities or changes in existing facilities. Iowa requires that a permit be obtained for any change in operation of an industry which would affect the character or amount of wastes from the process. The reporting health authority from Iowa stated that any change in railroad operation whereby polluting material would be increased should be preceded by plans submitted to the department of health so that a permit can be issued if the waste disposal system is deemed adequate.

All of the laws provide penalties for violation of the regulations in the form of fines and imprisonment and some of them are large in amount. Each day of violation is usually considered as a separate offense.

Canada

All of the provinces of Canada have laws in effect to control the pollution of streams and some of these laws were enacted as early as 1896. They are similar in requirements and administration to those of the states discussed above.

International Law

There is a treaty between the United States and Great Britain relating to boundary waters between the United States and Canada. An international joint committee has existed under this treaty since 1912 and one of its objectives is the regulation of pollution in international waters. The Detroit and Niagara rivers are under study at the present time.[3]

Interstate Agreements

There are three interstate agreements which do not have enforcement authority and have not been ratified by Congress, but the signatory states agree to cooperate with each other in pollution control and regulation. One of the early members of this group is the Great Lakes Drainage Basin Sanitation Agreement, signed in 1928 by Wisconsin, Minnesota, Illinois, Michigan, Ohio, Pennsylvania, New York and Indiana, which requires primary treatment for sewage as a minimum. The Upper Mississippi River Drainage Basin Sanitation Agreement, effective in 1935 between Minnesota, Iowa, Wisconsin, Illinois and Missouri, does not specify any minimum treatment requirements but is a cooperative effort to control pollution. More recently the Interstate Sanitation Committee was formed between North Dakota, South Dakota and Minnesota, and this agreement calls for treatment to produce a maximum B.O.D. of 25 ppm. with 20 ppm. suspended solids.

There are at present five interstate pollution control compacts which have enforcement authority and have been ratified by Congress for pollution control in interstate waters. These are as follows:

1. The Interstate Sanitation Commission, comprising New York, New Jersey and Connecticut, was formed in 1936 and issues orders regulating pollution. Streams are zoned and two classes of streams are set up with minimum requirements for each based on use as public water supply sources.

2. The Interstate Commission of the Delaware River Basin was put into effect by terms of reciprocal legislative agreements between New York, Delaware,

[3] K. S. Watson, "Ohio River Compact and Other Interstate Agreements," Journal American Water Works Association, Vol. 41, January 1949.

considered toxic they can contribute to the formation of turbidity and sludge banks and result in depletion of aquatic life. As for the washing effluents from zeolite plants and demineralizers, these should be diluted if necessary to meet the requirements of the classification of the stream being used for disposal.

Commercially available machinery and processes for waste treatment are being rapidly developed. Thickeners, settling basins, separators, oil traps, filters, etc. can be purchased as units to fit the situation from the water treating equipment manufacturers. Flow sheets and methods of treatment for various products are available from the same source.

Conclusion

Legal control of stream pollution is now well under way and will generally govern waste disposal from railway and other industrial property. At the present time the regulations are going through a development stage with stream zoning as the probable goal with zones based on uses of the streams. The fact that the regulatory bodies seem disposed to work with representatives of industry rather than to take an arbitrary stand is brought out in the first report, July 27, 1949, of the Water Pollution Control Advisory Board which was established under the Water Pollution Control Act. This board consists of six nongovernment leaders in water pollution abatement appointed by the President, and five members taken from the Public Health Service, Department of the Army, Department of the Interior, Federal Works Agency, and the Department of Agriculture. This board brings industry and government together in the problem of pollution abatement. The board takes the stand that the degree of treatment required should fit the situation and that the quality of water in the receiving stream should be maintained in a condition commensurate with the reasonable and desirable uses of the stream. It recognizes the self-purification capacity of streams and aims to bring discharge of wastes in excess of the assimilating capacity under control in an orderly fashion.

Your committee agrees with the health authority who reported that in normal railway operation there should be no major problems which could not be cleared up and prevented by good housekeeping and an informed operating personnel. Thus those railroads which now provide the personnel and facilities for handling such matters will undoubtedly save themselves much trouble and duplicated expense in the future.

Report on Assignment 8

Inspection and Maintenance of Steel Water Tanks

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This is a final report offered as information.

Steel water tanks and standpipes should be carefully inspected at regular intervals of not more than five years in order to guard against excessive loss of metal resulting from the corrosion of inadequately protected surfaces. If the water or atmospheric condition is unusually severe, more frequent inspections are necessary. The loading on the tank tower structure of a 100,000-gal. steel tank is approximately 965,000 lb. and the reduction in sectional area and strength of the structural steel due to corrosion may lead to serious weakening or failure of the structure.

TABLE 1.—RAILWAY OPERATING WASTES REPORTED BY HEALTH AUTHORITIES

No Specific Examples	*Oil, Oily Products Creosote, Etc.*	*Fecal Matter Kitchen Wastes*	*Sludge from Treating Plants*
Alabama	Arizona	Arizona	Illinois
Arkansas	California	Connecticut	Iowa
Georgia	Florida	Florida	Kansas
Kentucky	Idaho	Michigan	Minnesota
Maine	Iowa	New York	North Dakota
Maryland	Massachusetts	Rhode Island	Oklahoma
Mississippi	Michigan	Texas	Texas
New Hampshire	Minnesota	Wisconsin	West Virginia
New Jersey	Missouri		
South Carolina	Nebraska		
South Dakota	Nevada		
Utah	New Mexico		
Wyoming	New York		
	North Carolina		
	North Dakota		
	Ohio		
	Oklahoma		
	Oregon		
	Pennsylvania		
	Tennessee		
	Texas		
	Virginia		
	Washington		
	West Virginia		
	Wisconsin		

TABLE 2.—RAILWAY FACILITIES MENTIONED BY HEALTH AUTHORITIES AS POLLUTION SOURCES

Repair Shops Machine Shops Terminals	*Roundhouses*	*Car Washing and Tank Car Cleaning*	*Railroad Yards*	*Timber Treating Plants*
California	Illinois	Indiana	Massachusetts	Wisconsin
Idaho	Michigan	Michigan	North Carolina	Virginia
Indiana	Nebraska	Nevada	New York	
Michigan	New Mexico	Oklahoma	Pennsylvania	
Minnesota	Ohio	Texas	Tennessee	
North Carolina		West Virginia		
Ohio				
Virginia				

2. Domestic sewage cannot be dumped into streams or lakes without at least having been given primary treatment.

3. Toxic chemicals must be kept out of or removed from wastes which will be placed in streams or lakes. This includes chromium compounds, acids, alkalis, and the various toxic chemicals which might be the result of draining and cleaning diesel engine cooling systems. cleaning and repairing freight cars, etc.

4. Mill wastes such as sawdust, chips, etc. must not be dumped into public waters or placed on their banks where there is liklihood that they will be washed into the waters .

5. There are only certain classes of streams which can be used for disposal of sludge from lime soda ash water treating plants. While these sludges are not

Preparation

The surfaces should be cleaned free from all loose paint, scale, and rust before paint or any other protective coating is applied. Special care should be used to clean all pits and those parts difficult to reach. Paint or mill scale which adheres firmly to the steel need not be removed.

If the paint is in good condition, cleaning may be done by means of scalers, scrapers and wire brushes. Either hand or power driven tools may be used.

When the condition of the metal is such that the wire brushes and scrapers are inadequate, the blasting method should be used, with either chilled steel shot or coarse silica sand. Whenever metal is cleaned by blasting, it must be given the prime coat of paint as soon as possible on the same day.

Painting

It is recommended that painting be done at intervals of from five to six years to prevent too much damage to the tank from corrosion. When the paint is exposed to unusually severe conditions, more frequent painting will be necessary. It is important that the inside of the tank receives as much protection as the exterior since most of the corrosion on the tank shell takes place from the inside. Cathodic protection has eliminated most of the need for painting the underwater surfaces. However, the tank shell should be painted from the rim to five feet below the water line. Cathodic equipment must be maintained and kept in operation if maximum protection is to be expected. Improved design of the equipment and correct electrode spacing have provided maximum economy and freedom from operating difficulties.

For protecting the interior underwater surfaces, a paint must be used that is inherently impermeable to moisture in order to give maximum protection and extended durability. It is important that sufficient drying time be allowed between the application of each coat and also before filling the tank with water. Some of the types of paint that have proved effective in this service are as follows: Red lead and linseed oil containing a small amount of litharge for a hardener, special bituminous coatings, aluminum paints, petroleum compounds and other quality coatings that have been developed to give maximum protection to the steel when submerged in water.

For the exterior of the tank and the underside of the roof, red lead in linseed oil when covered with a finishing coat of caıbon or iron oxide paint forms a very durable coating and will protect the steel from corrosion under most conditions for a long period of time. Chromate of lead pigment paints also make excellent priming coats but are relatively high in cost as compared to red lead. For best results these paints should be covered with two water-resistant finishing coats. Aluminum paint or black graphite may be used for finishing coats over a rust-inhibiting primer. Petroleum compounds are especially effective on the underside of the roof.

Paint should be applied only to a clean and perfectly dry surface, when the temperature is 40 deg. F. or above. Whether paint should be applied by spray or brush is largely an economic consideration as either method will produce an equally durable coating. The cold application type coatings should be thoroughly rubbed into all depressions of the metal with a stiff brush to prevent the material from bridging over such a depression and leaving parts unprotected.

Adequate ventilation inside the tank is essential both to protect the workmen and to provide the necessary air for quick drying.

After painting has been completed on a tank that is being used for drinking water purposes, it should be sterilized in accordance with board of health requirements.

Corrosion of iron and steel is a chemical action which tends to cause the metal, when exposed to moisture and air, to revert to a form in which it was originally found in the earth. Under conditions of exposure, iron corrosion is composed mainly of ferrous hydroxide next to the metal with ferric hydroxide forming the outer cover. Where iron corrodes in the atmosphere the amount of ferrous hydroxide is small, but when formed under water there is a larger proportion of the ferrous iron. The rate of corrosion of the interior underwater surfaces of a tank is almost directly proportional to the oxygen concentration in the water, provided other factors do not change. An increase in the pH value of the water causes a decrease in the corrosion rate.

Corrosion of the surfaces exposed to the atmosphere is influenced by the length of time the tank remains wet, by the extent and kind of atmospheric pollution, and the presence of condensed moisture in the rust film. Moisture is the main controlling factor. The action of hydrogen sulfide, sulfur dioxide, and other substances in the air is much more rapid in moist than in dry air.

Inspection

It is recommended that the tank be drained completely and the inside surfaces washed down so that the sides and bottom of the tank and riser can be properly inspected. All loose deposits and mud should be removed from the bottom.

When making the inspection, particular attention should be paid to the following details:

1. Anchor bolts should be examined for corrosion that may have reduced their strength.
2. Column shoes should be watched for dirt accumulation and pockets which will hold water and cause serious rusting. They should be grouted with a mixture of sand and asphalt so that water will not run under them.
3. Tower posts should be inspected for alinement and possible foundation settlement. Examine particularly the condition of tower rods around pins and see that they are properly adjusted. These rods should not be removed for cleaning and repairing except when the tank is empty and adequately braced to prevent a possible collapse of the structure.
4. Examine all clevis pins for cotter pins because a missing clevis pin will loosen the tank bracing and the structure may collapse.
5. Inside and outside ladders should be inspected for weakened lugs and missing bolts that would make them unsafe. The revolving ladder on the roof should be inspected for a poor connection at the finial.
6. The condition of the roof metal should be checked along with the spider rods. If the spider rods are found to be in a dangerous condition, they should be removed but need not be replaced as they are for construction purposes only.
7. The tank shell and riser should be inspected for pitting, loose rivets, and leaky seams.

Repairing

Before repainting it is necessary that all badly corroded parts be either repaired or replaced. It is not recommended that extensive welding be done on the tank shell but that the sheets be replaced where practical. Loose rivets and leaky seams should be caulked. A flat head rivet may appear to have lost a large portion of its head but a rivet does most of its work in shear and very little in tension. As long as the rivet is tight it does not have to be replaced.

Incrustation due to calcium and magnesium salts is likewise found when raw waters are used to desuperheat steam or are sprayed into a steam main in an attempt to control corrosion. This type of incrustation is easily controlled by the addition of soft water in the cause of desuperheating, and in corrosion control by the careful addition of the proper amount of raw water by means of an orifice, or a flocontrol valve where it is desirable to vary the amount injected due to changing load conditions. Only that amount needed to form a $CaCO_3$ film should be used since excessive use will manifest itself by incrustation throughout the entire system. Further incrustation will be found where cooling water is used indiscriminately in the pump of a vacuum return system. It may well be desirable to obtain greater efficiency of the pump by the addition of cold water, but since these pumps are usually isolated and not adjacent to a soft or organically treated supply, the cooling water is taken from a raw water line, and lack of supervision frequently results in the use of excess water which leads to uncontrolled incrustation. Supervised control will usually provide that amount of water needed for good operation, as well as film formation for corrosion prevention in the return line to the power plant.

Another type of incrustation that offers difficulty is that which is more or less localized in the low velocity areas and at impingement points, and which consists of iron oxides and hydroxides bound together into a putty like mass with absorbed oil. Ordinarily the slight, dusty iron corrosion products would be carried through the system, but at plants where the exhaust from reciprocating power is used for heating the feedwater, the excess oil will be carried through the heater due to an inefficient oil separator or neglected maintenance. This oil enters the boiler and is vaporized or distilled with the steam into the heating system. Unfortunately this oil does not adhere to the piping to form a protective film, but is more readily absorbed by the flocculent iron hydroxides. This type of incrustation is minimized by reducing oil consumption in the reciprocating engines or steam pumps, by proper attention to the oil separators, and where necessary by the installation of oil removal filters. Many types of waters when internally treated, will by reason of the absorbing properties of magnesium hydroxide remove the larger portion of the oil from the boiler waters, and it is thus disposed of through the blow-off cock with the sludge. Usually the greatest difficulty will be found with very soft feedwaters. Oil is sometimes fed into a new system to give the lines a protective coating, and light oils are fed continuously to maintain a coating, but this practice seems to be waning since results have not proved satisfactory.

Corrosion

Physical Aspects

The important and most costly replacements are due to corrosion. Sometimes entire systems fail due to corrosion in the threads alone and failure at that point has brought about serious outages, for it is possible to have complete severance of the line allowing hot condensate to discharge on the storage below. Failure at threaded joints is more frequent since considerable metal has been lost due to threading, especially if the joint is shouldered. Probably the most significant phenomena are the unrelieved stresses that are set up when the pipe is threaded. These stresses are intensified by poor dies or workmanship, and result in fatigue corrosion which may cause complete failure at the threads even though the oxygen and carbon dioxide present may have only slight action on the balance of the pipe.

The importance of the proper construction of return piping can not be over emphasized. The presence of condensate pockets will result in pipe failure in the return as well as in steam piping. Steam lines which are inadequately insulated and drained will

Conclusions

Proper inspection and maintenance of steel water tanks is essential because of the investment involved and the excessive cost to replace them at current prices. With proper protection the useful life of steel water tanks can be prolonged indefinitely.

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Report on Assignment 9

Corrosion and Incrustation in Return Systems

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This final report is submitted as information.

Corrosion and incrustation of steel piping has been an annoyance for a long time but only during recent years has seemed to be a serious problem. In the past considerable piping was replaced by maintenance crews without much thought of the requirements for long service life, because it was considered to be simply normal maintenance procedure. However, losses due to corrosion or other causes were forcibly brought to attention by the increased cost of the replacement piping and, during the war years, by the scarcity of both pipe and labor. Further, there is a marked tendency toward the more economical heating of terminal facilities and many smaller buildings by centralized facilities in place of stoves or small heating plants, thus requiring the construction of steam mains and return piping from the existing power plant that normally furnished steam for roundhouse or shop use. Therefore, the amount of piping being exposed to the corrosive action of condensate has greatly increased, making maintenance and replacement a more noticeable and extensive item.

Incrustation

Incrustation of return piping appears to be the least troublesome; it is not found as extensively in late years, due to greatly improved boiler feedwater treatment. Formerly there was little or no treatment, and the more soluble salts would cencentrate and be carried over with the steam along with the precipitated sludge due to foaming and priming. The calcium sulfate and the silicates acting as binders for carried over sludge and iron oxides soon accumulated progressive films of scale which eventually caused complete obstruction of the lines. It has sometimes been the practice to cause priming intentionally for the purpose of carrying over sufficient alkaline water from the boiler to control the line corrosion, but the carryover of the high surface concentration of sludge has caused incrustation of lines and poor functioning of traps. This practice has now been largely discontinued. Today foaming and priming may be controlled with polyamide and similar antifoam materials precluding the formation of this type of incrustation.

Control of Corrosion

It is doubtful if corrosion can be competely eliminated in an entire system, but there are precautions and practices that can be followed to preclude its running an unchecked course.

Selection of a suitable water with the proper treatment is of prime importance. Surface waters naturally contain considerably more dissolved oxygen than deep well supplies, but usually the surface supplies are selected because of their lower hardness and lesser treating costs. In such cases dependence is placed on de-aerating heaters for oxygen removal. High bicarbonate waters treated with sodium zeolite give the most troublesome corrosion in condensate systems since the resulting sodium bicarbonate breaks down to sodium carbonate and finally to caustic soda with the release of carbon dioxide with the steam in the process shown in the following equation:

$$NaHCO_3 + \Delta \leftarrow NaOH + CO_2$$

This suggests that any treatment giving high sodium bicarbonate in the boiler water should be avoided and that consideration be given to acid treatment followed by degasification of the sodium zeolite treated water. This also holds true when using excess phosphate treatment with raw waters containing high carbonate alkalinity. Internal treatment should be selected to bring about removal of the carbonates as calcium carbonate, using phosphates to remove the final traces of calcium. The indiscriminate use of soda ash should be discouraged, and the use of a caustic type of internal treatment in indicated. It is assumed that these chemicals will be supplemented with organic additives.

There are several methods of treatment that will reduce potential carbon dioxide concentration in the steam phase: Complete demineralization, or hydrogen zeolite softening followed by degasification, hot process lime soda and cold process lime soda using the lowest possible excess of reacting chemicals; the type selected being governed by the water composition. Removal of the carbon dioxide from the reaction in case of hydrogen zeolite softening by aeration saturates the water with oxygen but this will be removed by a properly operated de-aerating feedwater heater.

It is realized that limitations may be involved both as to available space for extensive softening facilities, and likewise the size of the steam generating facilities may limit the amount of the investment involved. To minimize corrosion under these circumstances several suggestions should be considered. (1) Check the boiler treatment, keeping in mind reduction of the amount of carbon dioxide forming chemicals since these should be kept at the lowest dosage possible. (2) Reduce blowdown to the lowest possible amount by making tests to determine carryover point. If steam tests indicate a slight carryover this will not be objectionable as it will reduce the acidity of the condensate. (3) Investigate condensate losses and return all that is possible economically, since this materially reduces the amount of feedwater necessary as well as the chemical required for treating. (4) If the plant includes an open feedwater heater and exhaust steam does not provide a sufficient source of heat to keep the temperature of the water at a point corresponding to the operating pressure of the heater, consideration should be given to adding live steam to complete the removal of dissolved gases. The heater should be examined and attention given to proper venting to dispose of removed gases. (5) The addition of catalyzed sodium sulfite to the feedwater will remove practically all traces of oxygen remaining after the feedwater has passed through the heater and also may be used to improve the results of a poorly functioning heater.

If after the basic causes of corrosion have been corrected there are adverse factors that do not warrant excessive capital expenditure and corrosion remains a problem it may

accumulate condensate which will be acidic by reason of the CO_2 gas in the steam dissolving in the condensate to form carbonic acid. Steam leaves the boiler as a gas thoroughly mixed with any CO_2 or O_2 and no solution of the gases occurs until the steam condenses, when immediate solution of all gases takes place, the extent of which depends entirely on the temperature of the condensate. Therefore, to avoid corrosion it is very necessary to have lines well insulated and to have all lines laid with even, adequate drainage, and trapped at all low points. Most important is stringent maintenance of all traps to maintain proper functioning.

Vacuum returns systems are subject to more serious corrosion because the lines are difficult to keep tight, allowing admission of oxygen from the atmosphere. This is especially true where the steam contains considerable amounts of carbon dioxide caused by excessive makeup or improper treatment. The same conditions are found in low pressure, intermittent heating systems, since shutting down causes cooling and condensation which results in the infiltration of air into the system through leaky joints, packing glands, and relief valves. Constant vigilance must be exercised to minimize oxygen accumulation.

Considerable wasting away of metal in both steam and return lines is found where improperly grounded electric circuits or improperly located high voltage lines parallel pipes in tunnels, or conduits induce stray currents which cause electrolysis; this trouble can be eliminated by proper conduit grounding and relocating of the lines or wires. Mill scale also can be a cause of localized pitting since the particles are cathodic to the metal and electrolytic cells are set up. This, however, is a minor factor and usually does not contribute to progressive deterioration.

Chemical Aspects

It has been generally conceded that return and steam line corrosion is due to the action of carbon dioxide and oxygen on the metal. Oxygen corrosion manifests itself by means of pits or area corrosion, whereas carbon dioxide attacks the bottom surface which results in grooving. Electrolytic corrosion is similar to oxygen corrosion and all oxygen must be eliminated before pitting can be attributed to electrolysis.

The reaction contributing to the loss of metal is basically between the carbonic acid and the iron and in the absence of oxygen the acidity of the condensate produces ferrous hydroxide and hydrogen, the metal surface remaining bright and free from any oxide protective coating. The free oxygen present accelerates the attack by the carbonic acid due to its depolarizing action and the reaction proceeds at a progressive rate until failure occurs. The reactions proceed as the following equations indicate:

$$H_2O + CO_2 \longrightarrow H_2CO_3$$
$$H_2CO_3 = H^+ + HCO_3^-$$
$$Fe^0 + 2H^+ \longrightarrow Fe^{++} + 2H^0$$
$$H_2O = H^+ + OH^-$$
$$Fe^{++} + 2OH^- \longrightarrow Fe(OH)_2$$
$$4Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3$$

It is shown that iron dissolves in the low pH value water and forms ferrous hydroxide which raises the pH, and this tends to diminish the solution of the iron. The presence of oxygen changes the reaction product to the insoluble ferric hydroxide and also removes the hydrogen film, allowing the reaction to sustain itself and proceed unchecked as long as more oxygen is supplied to the system. This indicates that to avoid and minimize condensate line corrosion both the oxygen and the carbon dioxide must be kept at the lowest possible concentration.

Report on Assignment 10

Control of Algae and Plant Growth in Water Storage Reservoirs

H. L. McMullin (chairman, subcommittee), I. C. Brown, G. E. Martin, W. A. McGee, Theodore Morris, J. Y. Neal, J. M. Short, D. C. Teal, J. W. Ussher, H. W. Van Hovenberg.

Your committee submits the following final report as information.

Algae include seaweed, pond scum, and a great variety of microscopic vegetation found in both fresh and sea water in countless numbers. Many are found in soils, on rocks and on tree trunks. Some grow on snow and ice, forming the so-called "red snow" of certain Alpine regions, and some are found in hot springs. No place has been found free of algae. Algae are classified into several groups, depending upon the color of the pigments in the cells. In addition to chlorophyll, a green pigment found in most algae, there are in some algae additional pigments such as blue, red and yellow. Green and blue-green algae predominate in fresh water, while the brown and red algae are found in salt water. This report deals primarily with the green and the blue-green algae.

Available food supply, temperature, hydrogen ion concentration and light intensity are the principal factors controlling the algae growth in a body of water. Soluble salts in water are the food upon which algae lives, and from these salts carbohydrates, fats and proteins are manufactured and converted into cell protoplasm by the process of photosynthesis. These salts are provided by the dissolving action of the water as it comes in contact with the earth and by bacterial action on organic matter picked up by the water in passing over the surface of the earth and from city sewers. Heavy algae growths can be expected in surface supplies in thickly populated areas and in streams receiving sewage from cities, although raw sewage in large amounts may be detrimental to algae growth. Due to the lack of organic matter and sunlight, deep wells are usually free of algae.

Temperature has a great influence on the rate of multiplication of algae but has little effect on the species. The most favorable temperature for the growth of most species of algae is between 57 and 70 deg. F., although certain other species such as the diatoms prefer the cooler temperatures of spring and fall. The green algae are usually most abundant in early summer, and the blue-green in early fall. The optimum hydrogen ion concentration or pH range for the growth of algae is from 5 to 7; however, algae may be found in waters with a pH range from 2.5 to 11.0, such as the blue-green algae found in limestone ponds with a pH of 9.3. A certain amount of light is required for the growth of algae, but light of high intensity destroys it. In surface blooms of blue-green algae, the exposed algae are destroyed in a short time by direct sunlight.

Algae are necessary in nature's scheme of things and without them, there would be no other forms of aquatic life. However, they are very troublesome at times, particularly to water works men. The most common difficulties in this connection arise from the tastes and odors imparted to water by the aromatic substances released by the cells, either living or dead. Algae cause other troubles such as discoloration, clogging of screens, strainers, filter beds and water lines, interfering with water flow. They also cause foaming of steam boilers, probably because of the oils released by dead and decaying cells. Other troubles caused by algae have been the death of farm animals poisoned by drinking water containing large amounts of blue-green algae and the mass fish killings due to the depletion of oxygen by the combined respiration of the algae and other organisms in polluted water during the night when photosynthesis stops. Algae which contain chlorophyll have the ability to split oxygen from carbon dioxide, using sunlight as a source of energy and to release free oxygen, which adds to the corrosive nature of the water.

be desirable to resort to steam modification. It has been proposed to remove the free carbon dioxide from steam condensate by means of volatile amines.* The amines volatilize with the steam and neutralize the carbonic acid in the condensate to form amine carbonate and bicarbonate and the pH can be raised to the desired point for arresting the corrosion. In serious cases of corrosion it has been found that the condensate pH will be as low as 4.8 and iron in solution as high as 25 ppm. Amine addition should be carefully controlled and only that amount added which is necessary to raise the pH to 6.0 or 7.0, since in systems where condensate loss is high it can be expensive. Amine treatment appears to be too high in cost in a "once through" system. Likewise it must be remembered excessive waste can occur by unregulated control of amine feeding since the hydrogen ion concentration is a logarithmic function. Tests have shown that carrying the pH of the condensate above 6.8 will give a solution free from soluble iron and consequently arrest condensate line corrosion.

The feeding of the amines can be handled proportionally or by slug feeding. Proportional feeding will give uniform treatment whereas slug feeding induces cycling. Either method will give results, but it is possible that slug feeding will waste more of the chemical, since losses are directly proportional to the steam and water losses. The design of some heating systems may indicate that only some areas are severely attacked by corrosion; these branches can be treated separately by means of a proportional feeder and thereby reduce overall treating costs.

Where it is found that condensate losses and excessive blowdown make the amines uneconomical to use, consideration can be given to ammonia or polyphosphate treatment. The feeding of ammonium sulfate in very small doses into the boiler feedwater will liberate ammonia gas which will pass off with the steam and dissolve in the condensate thus reducing the acidity and controlling the corrosion. This treatment must be used very carefully since ammonia in the larger concentrations will attack copper and its alloys. Escaping steam will also transmit the characteristic odor of ammonia into the surrounding atmosphere.

Polyphosphate treatment will in many cases control severe corrosion at a lessor cost. It must be fed continuously into the steam since the protective action depends upon the continuous film of an iron phosphate. Its advantage is marked in low pressure systems where amines are not volatilized and no feedwater heaters are installed. It is not recommended in systems containing closed feedwater heaters or economizers, or where the steam is used in conjunction with the operation of turbines.

Summary

Corrosion failures of steam and return piping must be thoroughly investigated to determine the basic difficulty. There may be physical as well as chemical causes for the difficulties and both should be investigated before remedial measures are taken. It is not always possible to eliminate the corrosion and incrustation completely and one may merge into the other, but in light of present knowledge the situation can be minimized and kept under control by the methods outlined.

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* Burk and Nigor, Bureau of Mines Technical Paper No. 714.

should be collected and removed, otherwise its decomposition may adversely affect the quality of the water, and the cutting should be done before the seed ripen in order to prevent increased distribution of the plants. Dredging affords more permanent results than cutting because of the partial removal of roots.

Underwater cutting machines, both manual and power operated, have been developed for cutting rooted plants. The manually-operated equipment consists of a ribbon steel saw which can be drawn back and forth across weedy areas. The power cutters are patterned after harvesting machinery and are operated from barges.

The mechanical methods of controlling rooted plant growth in impounding reservoirs are effective, but they are laborious and time consuming. In recent years the use of formagens such as 2,4–D for destroying plant growths has been practiced to a considerable extent. Concentrations of 1 lb. to 100 gal. of water can be used, and as little as one pound per acre has been found effective in controlling certain types of plants.

Whether the problem is presented by algae or by rooted vegetation, no definite rules of procedure or methods can be described which will fit all cases, and each problem must be given individual study to determine how the principles of control can best be applied.

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Since the algae population of a body of water depends upon food supply, temperature, hydrogen ion concentration, and light intensity, the control of any one of these primary factors suggests in itself a method of algae control. There is a growing conviction among sanitary engineers that the most successful method of combating algae will be by means of biological control. To date, however, the use of algicides is the most common method of algae control, and copper sulfate is probably the most common algicide used. Other compounds which are toxic to algae and have been used successfully are chlorine, creosote, fuel oil, chlorinated benzols, and sodium pentachlorophenate. With the exception of chlorine, these other algicides cannot be used in water taken for drinking supplies. Copper citrate is also used as an algicide; it and sodium pentachlorophenate are the bases of mixtures sold as algicides under trade names.

The amount of copper sulfate required to control algae depends upon the species of algae to be destroyed, varying from 0.05 ppm. for coelastrum to 10.0 ppm. for eudornia and pandorina, all in the class chlorophyceae or green algae. It also depends upon the temperature, organic content, the contact period allowed, alkalinity and pH of the water.

In using copper sulfate for algae control in water for human or animal consumption, or in which fish life is to be protected, close control of dosage must be maintained. Tables have been published showing the amounts of copper sulfate and chlorine required for treatment of different genera, and the tolerance of fish to copper sulfate. The dosage of copper sulfate should be increased or decreased by 2.5 percent for each degree of temperature above or below 50 deg. F., and increased 2 percent for each 10 parts per million of organic matter. 0.5 to 5.0 percent copper sulfate must be added for each 10 ppm. of alkalinity, and increased dosages are required as pH increases.

The methods of application of copper sulfate also vary somewhat. In some instances, it is scattered over the surface of the body of water being treated; in others, it is fed in solution form into the suction pipe of water pumps where it is mixed with the water being delivered to storage tanks. Probably the most common method of application is by dragging it in burlap bags behind boats, row and motor, over the surface of the body of water being treated. The boat in these instances usually follows a criss-cross or zig-zag course previously laid out so that the algicide will be well distributed and areas of high concentration avoided.

Chlorine is an effective algicide and will destroy many genera which survive copper sulfate treatment. It can be used with copper sulfate by mixing the two before application or by following copper sulfate treatment with an application of chlorine. Where many species of algae are involved a combination of the two will usually prove more effective than either one used alone. The use of chlorine in the treatment of impounded supplies is not convenient because of a lack of suitable means of uniform application.

Because of the lack of free and half-bound carbon dioxide, an important algae food factor, the usual lime-soda ash treated water will not support the growth of most algae. Activated carbon fed into settling basins in large amounts coats the walls of the basins and inhibits algae growth by shutting out sunlight.

Where water supplies are not to be used for human or animal consumption and where fish life is not to be protected, the selection of algicide and control of dosage need not be so rigid. This is usually true of railroad supplies and in such cases no harm will follow the use of harsher methods of treatment.

Rooted vegetation such as chara, pond lillies, water hyacinth and other types of water weeds cannot be destroyed by the usual dosages of the various chemicals used as algicides. Mechanical methods are usually employed in dealing with the larger plant growths. These consist of cutting the plants below water level and dredging. Cut material

Report of Committee 20—Uniform General Contract Forms

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

The Committee on Uniform General Contract Forms,

L. A. Olson, *Chairman.*

Report on Assignment 1

Revision of Manual

W. R. Swatosh (chairman, subcommittee), E. H. Barnhart, C. J. Henry, J. S. Lillie, A. A. Miller, O. K. Morgan, C. B. Niehaus. W. G. Nusz, L. A. Olson, G. W. Patterson, B. M. Stephens.

The committee recommends reapproval of the Form of Agreement for Purchase of Electrical Energy for Traction and Other Purposes (Manual pages 20–91 to 20–99) with minor editorial changes in "Witnesseth" clause and Articles 1, 2, 5, 13, 19 and 21; eliminating superfluous intermediate headings and revamping last paragraph of Article 7 to clarify "Maximum Demands."

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preserve the general service of the Power Company. In ascertaining the Maximum Demand for such months, hours, in which such abnormal demand or demands occur shall not be selected unless such abnormal demands occur in .... or more consecutive days; and in the latter event, hours in which such abnormal demands occur may be selected from any of such consecutive days following the .... of such consecutive days, but such hours shall be ignored in determining the Billing Demand for any month subsequent to the month in which such abnormal demand occurred and shall be ignored in determining the minimum number of kilowatt hours to be used in computing the Secondary Charge for that month.

The term "abnormally low temperature" shall be considered to mean a temperature of .... deg. F., above (or below) zero, or any lower temperature, as officially determined and recorded by the United States Weather Bureau at ....

13. Reduction of Primary Charge

In the first line, second paragraph, substitute the word "occurs" for "occur."

19. Reduction in Rates

In the first line, first paragraph, substitute the word "life" for "term."

In the first and second lines, second paragraph, substitute "life" and "its" for "term" and "their," respectively.

21. Right of Access to Railway Property

In the second line, first paragraph, substitute the word "life" for "period."

Intermediate center headings "Rates and Payments," "Metering," "Interruption, Default and Termination" and "General" appearing on pages 20–92, 20–94, 20–95 and 20–98, respectively, are to be deleted.

FORM OF AGREEMENT FOR JOINT USE OF POLES ON RAILWAY LANDS

The second paragraph of introductory clause and "1. Location" to be deleted and substituted with the following:

WITNESSETH:

WHEREAS, the Wire Company desires to establish locations of joint poles and joint use thereof and which are specifically marked on Exhibit "A," in accordance with plan No. .... dated .... entitled ...., and which is hereto attached and made a part hereof, and

WHEREAS, the Railway Company agrees to such locations and use subject to conditions hereinafter set forth,

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is mutually agreed as follows:

2. Ownership

In the last line, substitute the word "Exhibit" for "Schedule." The same substitution is to be made twice each in Articles 7 and 13.

Present articles numbered 2, 3, 4 and 5 are to be renumbered 1, 2, 3 and 4.

The Committee recommends reapproval of the Form of Agreement for Joint Use of Poles on Railway Lands (Manual pages 20–109 to 20–111) with the addition of "Whereas" and "Therefore" clauses, in order that this agreement may be in harmony with Manual agreements containing similar clauses, eliminating Article 1 by absorbing it in said "Whereas" and "Therefore" clauses and renumbering articles following Article 1 due to this absorption, subdividing present Article 6 "Liability Arbitration," and making editorial changes in articles headed "Ownership," "Custody" and Maintenance" and writing new Article 3.

The committee recommends reapproval of the Form of License for Pipes, Conduits, Drains, Hopper Pits and Other Structures on Railway Property (Manual pages 20–117 to 20–118) with the addition of "Whereas" and "Therefore" clauses in order that this agreement may be in harmony with Manual agreements containing similar clauses.

The committee recommends reapproval of the Form of Agreement for Placing Snow or Sand Fences Off the Railway Company's Property (Manual pages 20–119 to 20–120) with the addition of "Whereas" and "Therefore" clauses in order that this agreement may be in harmony with Manual agreements containing similar clauses.

The committee recommends reapproval of the Form of Agreement for Furnishing Water from Railway Water Systems to Employees and Others (Manual pages 20–121 to 20–122) with the addition of "Whereas" and "Therefore" clauses in order that this agreement may be in harmony with Manual agreements containing similar clauses.

The committee recommends that the Form of Option for Purchase of Land and Form of Conveyance of Title Granting the Right to Construct and Maintain Buildings over Railway Property (Manual page 20–123 and pages 20–125 to 20–128 respectively) be reapproved without change.

FORM OF AGREEMENT FOR PURCHASE OF ELECTRICAL ENERGY FOR TRACTION AND OTHER PURPOSES

The following minor editorial changes and revisions are recommended:

WITNESSETH:

Under Witnesseth, tenth line, substitute the word "Exhibit" for "Appendix."

2. Obligations as to Supply and Purchase

Print insert in italics.

5. Points of Delivery

Print insert in italics.

7. Determination of Demand

The last paragraph to be deleted and the following inserted in lieu thereof:

If in any month the Railway Company shall require an abnormal energy supply caused by excessive or congested traffic beyond that usually handled by the Railway Company or due to storm, abnormally low temperature, accident, complete or partial failure of the Power Company's supply of energy, derangement of the Railway Company's power facilities, or any other emergency condition, the Power Company will, if it has sufficient capacity available at the time, supply such abnormal demand, provided the Railway Company shall give the Power Company prompt notice of such abnormal demand by telephone or otherwise, confirming such notice by letter within forty-eight hours. The Railway Company agrees, however, to promptly reduce the demand to normal upon notification from the Power Company that such reduction is necessary to

FORM OF AGREEMENT FOR PLACING SNOW OR SAND FENCES OFF THE RAILWAY COMPANY'S PROPERTY

Under present "WITNESSETH" add the following:

WHEREAS, the Railway Company desires to erect and thereafter maintain a snow or sand fence upon the land of Licensor, and

WHEREAS, the Licensor is agreeable to such erection and maintenance subject to conditions herein set forth,

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is mutually agreed as follows:

FORM OF AGREEMENT FOR FURNISHING WATER FROM RAILWAY WATER SYSTEMS TO EMPLOYEES AND OTHERS

The present "WITNESSETH" clause to be deleted in its entirety and substituted with the following:

WITNESSETH:

WHEREAS, the Consumer desires to have the Railway Company furnish water from its source of supply, and

WHEREAS, the Railway Company is agreeable to do so subject to conditions herein set forth,

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is mutually agreed as follows:

Supplemental Report on Assignment 1

Revision of Manual

Revised Form of Agreement for Interlocking

G. W. Patterson (chairman, subcommittee), G. H. Beasley, A. B. Costic, G. K. Davis, C. J. Henry, C. E. McCarty, W. L. Mogle, W. G. Nusz, J. L. Perrier, Bruce Shaffner, W. R. Swatosh.

Your committee presents a draft of form of agreement for interlocking.

This matter was considered last year in connection with revision of the Manual, but it was found that the 1936 form, now in our publication, was so out of date and so lacking in coverage of the subject, that a complete rewriting would be necessary and the task was turned over to a subcommittee for handling.

Working closely with the Signal Section, AAR, your subcommittee has developed the form submitted herewith, and recommends that it be adopted for publication in the Manual, replacing the existing form entitled "Form of Agreement for Interlocking Plant."

New Article 3 is to be written as follows:

3. Specifications

Details of construction of said poles and the wires and fixtures thereto attached and the character and voltage of electric currents employed shall be governed by specifications No. ....

Each party shall take reasonable precaution to prevent interference of its wires on said poles, or of its system, or services of the other party.

6. Liability Arbitration (New 5)

This article to be subdivided as follows:

5. Liability

Each party shall, at its own expense, place and maintain its cross-arms, fixtures and wires and shall be responsible for the electric current employed by it in the conduct of its business, for loss of or damage to property (including poles, wires and fixtures maintained under this agreement) and for injury to or death of persons due solely to the act or neglect of such party. Each party shall pay its fair proportion of any such loss of or damage to property or injury to or death of persons due in part to its act or neglect and in part to the act or neglect of the other party.

6. Arbitration

In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the judge of the .... Court of .... The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

Articles numbered 7, 8, 9, 10, 11, 12 and 13 are to remain in present sequence.

FORM OF LICENSE FOR PIPES, CONDUITS, DRAINS, HOPPER PITS, AND OTHER STRUCTURES ON RAILWAY PROPERTY

The present "WITNESSETH" clause to be deleted in its entirety and substituted with the following:

WITNESSETH:

WHEREAS, the Licensee desires to construct, maintain and use ....
....,
upon the property of the Railway Company, situated ....
....
and substantially as shown on the plan hereto attached, designated as ....
....,
dated ...., and made a part hereof, and

WHEREAS, the Railway Company is agreeable to such construction maintenance and use subject to conditions herein set forth,

NOW, THEREFORE, in consideration of the mutual covenants herein stipulated to be kept by the parties hereto, it is mutually agreed as follows:

.... Company. All costs and expense of such future construction, maintenance, repair and renewal shall be borne by the parties hereto as follows:

....

....

3. Apportionment of Cost

(a) The cost of construction, maintenance and renewal of said interlocknig, as shown on "Exhibit A," shall be borne by the parties hereto in the proportion that the number of units installed for each party's benefit shall bear to the total number of units installed.

Table of signal and interlocking units based on Association of American Railroads Signal Section Table of Signal and Interlocking Units, "Exhibit B," dated ...., 19 ...., and unit distribution, "Exhibit C," dated ...., 19 ...., and identified by the signatures of ......(proper officers)...... of the .... Company and the .... Company, are attached hereto and made a part hereof.

(b) In the event that by mutual agreement of the parties hereto any change shall be made during construction of the interlocking, "Exhibit C" shall be revised in accordance with AAR Signal Section Table of Signal and Interlocking Units and the cost of constructing, maintaining and renewing the interlocking shall be borne by the parties hereto on the basis of such revised "Exhibit C."

(c) Each party hereto shall participate in the ownership of said interlocking in the ratio which the payments made by it for construction of said interlocking, including changes chargeable to capital account, bear to the total cost of construction thereof.

(d) The cost of maintaining and renewing the interlocking, including repairs of damage due to fire, action of the elements, strikes or other contingencies, shall be borne by the parties hereto in the proportion that the number of units installed for each party's benefit bears to the total number of units.

Any expense, other than for normal maintenance, made necessary by an act, law or ordinance of a lawfully constituted public authority shall be borne by the party required to make the change.

(e) Each party hereto shall, at its option, carry insurance on its equity in the interlocking.

(f) Each party hereto shall report its interest in the interlocking as may be required for taxation purposes.

(g) The cost of operating the interlocking, including wages of signalmen, personal expenses, if any, and cost of signalmen's supplies, heating, lighting and cleaning the buildings shall be borne by the parties hereto as follows:

....

....

(h) That portion of the cost of wages of signal forces, and personal expenses, if any, which is chargeable to operation, together with the cost of materials used in connection therewith, shall be divided between and borne by the parties hereto on the same basis as the cost of maintaining the interlocking.

(i) The cost of removing any existing safety appliances or devices shall be divided in the same manner as the maintenance and renewal expense of said appliances or devices has heretofore been divided.

FORM OF AGREEMENT FOR INTERLOCKING PLANT

1949

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the .... Company, and ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the .... Company.

WITNESSETH:

WHEREAS, ...

(Note: Insert brief description of conditions, including location of existing facilities; enumerate any existing agreements giving dates, interested parties and purposes.)

...., and

WHEREAS, the parties hereto mutually desire to construct, maintain and operate an interlocking at said location, the type and arrangement of the interlocking to be substantially as shown on plan marked "Exhibit A," dated ...., 19 ...., further identified by the signatures of ....(proper officers)............ of the .... Company and the .... Company, attached hereto and made a part hereof, and

WHEREAS, the parties hereto desire to define the ownership of existing facilities, and their rights and obligations with respect to the proposed interlocking;

NOW, THEREFORE, in consideration of the premises and of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Definition

The term "interlocking" as used herein shall be held and taken to include the interlocking station, power plant, buildings, housings, machinery, appliances and appurtenances necessary for operation of the interlocking system within the limits as shown on "Exhibit A," but shall not include ties, rails, insulated joints, other track materials or special items as provided in Article 6 hereof.

2. Construction

(a) Subject to approval of proper public authorities, the .... Company shall construct the interlocking substantially as shown on "Exhibit A," shall begin the construction within .... days after the date of such approval, and shall carry the work forward to a prompt completion.

(b) Each of the parties hereto shall, at its own expense, reconstruct and realine its tracks to conform to the arrangement of tracks as shown on "Exhibit A," excepting that ....

(Define responsibility for construction and maintenance of any rail crossings, jointly owned turnouts, etc., to accommodate existing tracks)

*(c) Each of the parties hereto shall have the right to construct additional tracks at this location. The construction, maintenance, repair and renewal of all ....(crossing frogs, switches, etc.)......... and other junction appurtenances for future tracks of either party hereto shall be under the sole charge and control of the

* This paragraph to be used only if applicable or mutually agreed upon.

of such intention and provided further that the use of such employees does not interfere with the prompt handling of signals.

(3) If for any reason it becomes necessary to temporarily take the interlocking out of service, the maintaining company shall provide and control the necessary flagmen, and the expense of such flagmen shall be borne by the company necessitating the service.

6. Material and Labor Supplied

Each of the parties hereto shall furnish and install its own derails, switch points, switch rods, special switch and derail ties and timbers, all track insulations, poles, cross arms and fixtures, except as otherwise provided, and shall maintain and renew them thereafter. Each party hereto shall do all the grading and track work necessary to prepare its tracks for the installation of the interlocking, provide and maintain proper drainage, and shall bear the cost and expense of raising and adjusting pipe carrier and mechanism foundations, and the renewal of any other appliances required or made necessary by its resurfacing, reballasting or rail renewal within the limits of the interlocking.

Each party hereto shall have the right to carry its respective signal control circuits through the interlocking at its own expense, provided, however, that work within home signal limits shall be performed by the forces of the party maintaining the interlocking, or under its supervision, at expense of the party for whose benefit the work is done.

7. Precedence

In the use of the interlocking, passenger, mail and express trains shall have precedence over freight trains and light engines; and freight trains shall have precedence over light engines. When of like class, trains and engines shall have precedence in the order of their arrival.

8. Payment of Bills

All payments hereunder shall be made within thirty days after rendition of proper bills.

The .... Company shall render bills covering the cost of constructing the interlocking, such expense to be billed in one statement unless otherwise agreed upon by the parties hereto.

Itemized bills covering the maintenance, operation and renewal of the interlocking shall be rendered monthly by the .... Company.

Such bills as are based upon payroll cost of labor and stock prices of material shall include a fair arbitrary charge to cover supervision, inspection, handling, transportation, accounting and similar undistributed items of expense. Such a fair arbitrary charge shall be in accordance with the recommendations of the General Managers' Association of ...., in effect from time to time, or in the absence of any such recommendations, shall be agreed to by the parties, or determined by arbitration as hereinafter provided.

Should dispute arise as to the correctness of any items included in bills rendered under this agreement, the party against which such bills are rendered shall pay all items included in the bills, and the correctness of disputed items shall be determined and proper adjustment allowed in future bills.

9. Liability

For the sole purpose of determining the manner of contribution between the parties hereto where either may suffer loss or damage or be liable for loss or damage to property or injury to or death of persons (all hereinafter called "damage"), caused by or at-

(j) If either of the parties hereto shall require communication service in connection with operating the interlocking, resulting in additional wages or other expense, the party requiring such service shall bear the additional cost thereof. In case both of the parties hereto shall require such special service the cost thereof shall be borne as follows:

....

....

4. Changes

Each of the parties hereto shall have the right to require changes in the interlocking, provided they shall not impair its efficiency. Such changes, arising from changes made in any existing track or tracks, or made to cover any future track or tracks or other facilities which either party hereto may have the right to construct, or which may be required by reason of any changes made in the standard appliances or practices of either party hereto, or which may be ordered by a lawfully constituted public authority, shall be made by maintaining company, or by other agreement, and the cost of such changes, including the cost of flagmen required in lieu of the interlocking shall be borne by the party hereto for whose benefit the changes are made. It is agreed that the word "benefit" as herein used shall include changes made to meet requirements of any public authority. When changes are made a revised "Exhibit C" shall be prepared and the cost of maintaining and operating the interlocking shall be borne and paid for by the parties hereto on the basis of such revised "Exhibit C."

5. Control of Interlocking

(a) *Maintenance*

(1) The maintenance and renewal of the interlocking shall be under the sole charge and control of the .... Company, and it shall employ competent persons to maintain and renew the same, and such employees shall be disciplined or removed for good and sufficient reason.

(2) Each of the parties hereto, through its authorized employees and representatives, shall have the right at all times to inspect the interlocking, also the accounts covering its construction, maintenance, renewal and operation. In the event that the .... Company shall notify the maintaining company, in writing, of repairs and renewals that may be necessary for the safe and proper operation of the interlocking, and if the maintaining company neglects to make the necessary repairs and renewals, then the complaining company shall have the right to make such repairs and renewals, and the maintaining company shall, upon presentation of proper bills, and within the time provided in Section 8 hereof, pay its proportion of the amount so expended.

(3) Each of the parties hereto shall, at its own expense, keep all pipe lines, switches, derails, and their connections, in or along its own tracks free from ice, snow, dirt, vegetation or other obstructions which may interfere with proper working of the interlocking. In case either party fails to do so, the other party may enter upon the premises of the party at fault and remove such ice, snow, dirt, vegetation or other obstruction. The party at fault shall reimburse the party doing such work for all expense incurred thereby.

(b) *Operating.*

(1) The operating of the interlocking shall be under the sole charge and control of the .... Company, and it shall employ competent persons to operate the same. Such employees shall be disciplined or removed for good and sufficient reason.

(2) Either party hereto may use the signalmen at the interlocking in its communication service, provided it shall give the other party at least ten days, prior written notice

a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the judge of the .... Court of .... Where signal practices are involved, the Arbitrator shall be one thoroughly conversant with signal practices and requirements.

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the Arbitrator.

11. Cancellation of Conflicting Agreements

The agreement dated ...., 19 ...., between the parties hereto or their predecessors is hereby terminated. Except as herein modified any and all other agreements between the parties hereto or their predecessors shall continue in full force and effect.

12. Duration and Succession

This agreement shall take effect on the .... day of ...., 19 ..,. and shall continue in force during the existence and operation of the interlocking or until terminated by the mutual agreement of the parties hereto.

The provisions of this agreement shall be binding upon and inure to the benefit of the parties hereto, their successors, lessees and assigns.

In Witness Whereof, the parties hereto have executed this agreement in .... the day and year first above written.

Attest:	.... *Company*
....	By ....
Secretary	
Attest:	.... *Company*
....	By ....
Secretary	

Report on Assignment 2

Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects

W. D. Kirkpatrick (chairman, subcommittee), E. H. Barnhart, G. H. Beasley, H. F. Brockett, A. D. Duffie, C. J. Henry, J. R. E. Hiltz, L. J. Hughes, A. A. Miller, W. L. Mogle, C. B. Niehaus, W. G. Nusz, G. W. Patterson, E E. Phipps, Bruce Shaffner, B. M. Stephens, J. L. Way.

Your committee submits the following tentative draft of agreement as information.

The Manual, at present, does not contain a form of agreement for division of work, maintenance and operation of flood control projects located upon lands and right-of-way of a railway company. The committee has drafted a form of agreement which it believes will provide for division of work and will permit the maintenance and operation of flood control works, so located, to be progressed under the control of the railway and assure minimum interference with the operation of trains.

tributable to the construction, maintenance, renewal, operation and operating the interlocking as herein provided for, it is agreed that employees of either party hereto when engaged in performing service or doing work as provided for in Articles 4, 5 (a) (3) and 6 hereof shall be construed as the sole employees of the party hereto required to ultimately pay for such service and work; employees of either party hereto when engaged in performing service or doing work as mentioned in Articles 2, 5 (a) (1) and (2), and 5 (b) (1), (2) and (3) hereof shall be construed as the joint employees of parties involved, provided, however, that such joint employees when performing services solely for the benefit of one of the parties hereto shall be construed as the sole employees of the party hereto for whom at the time such services are being performed; and that said contribution shall be determined and paid as follows:

(a) Each party hereto shall assume, bear and pay, and shall indemnify, protect and save harmless the other form, all damage attributable to the fault or negligence of its sole employee or employees, whether or not concurring with that of a joint employee or employees, excepting only as provided in Paragraph (b) of this Article.

(b) Each party hereto shall assume, bear and pay all damage to its property, to property under its control or in its custody, and to its sole employees and persons in or upon its engines, trains, or cars, attributable to failure to properly construct, maintain or renew the interlocking, or when attributable to the fault or negligence of its sole employees combined with the fault or negligence of the sole employees of the other party hereto, or solely to the fault of one or more joint employees, or one or more joint employees and the sole employees of parties hereto, or unknown or concealed causes; all other damage, when so attributable, shall be assumed, borne and paid by the parties hereto in the same ratio as the costs of maintaining and renewing the interlocking were divided between them during the period in which the damage occurred.

In case of death or injury due to fault or negligence as defined above, occurring to employees upon the property covered by the terms of this agreement, in which case under any law, state or federal, compensation is required to be paid, such compensation shall be distributed between the parties hereto as in case of liability provided in this Article.

In every case of death or injury occurring, without fault or negligence as defined above, to a sole employee, the party employing such employee shall be solely responsible for any compensation required by law to be paid by reason of such death or injury.

In every case of death or injury occurring, without fault or negligence as defined above, to a joint employee as hereinbefore defined, the compensation required by law to be paid on account thereof shall be paid solely by the party hereto for whom service is being performed at the time of such death or injury. In the event that both parties are being served at the time such death or injury is caused, all consequent payments resulting therefrom shall be borne by the parties hereto in the proportion shown in "Exhibit C."

If and when compensation is required to be paid in installments over a period of years, the future payments shall be distributed between the parties hereto in the same ratio as the first payment. No party shall be released from the payment of its share of such installments for which it may become liable by the cancellation or termination of this agreement.

10. Arbitration

In case any question arises under this agreement or concerning the subject matter thereof, upon which the parties hereto cannot agree, such question shall be settled by

tracks and facilities which will be located thereon when said flood protection work shall be completed, as well as the right, at any and all times thereafter, to construct, maintain and operate such additional railway tracks and facilities on said premises as Railway, its successors and assigns, shall deem necessary, but not in such a manner as to interfere with the construction, operation and maintenance of the flood protection works or impair the stability or usefulness of said flood protection works.

2. Right of Entry

Railway hereby grants to Government and Public Authority, their respective contractors, agents, officers and employees, the right, at their own risk, to enter upon Railway's lands to construct, maintain, repair, operate, inspect or in event of abandonment to remove said flood control works with the understanding that:

(a) No entry will be made on Railway's lands until its operating superintendent has been notified and arrangements for maintaining and protecting rail traffic have been agreed upon between Public Authority and Railway.

(b) Equipment, tools and materials will not be used, stored or placed closer than .... feet from the near rail of the nearest track, except that explosives or other highly inflammable substances will not be used, stored or placed closer than .... feet from the near rail of the nearest track.

3. Work to be Performed by Railway at its Expense

The following work will be performed by Railway entirely at its own expense, in order to supplement the work to be performed by Government and Public Authority.

Item	*Mile Post*	*Description*

4. Work to be Performed by Railway at Government's Expense

Subject to being reimbursed by Government as hereinafter provided, Railway, in addition to the work to be undertaken and performed by it pursuant to paragraph 3 hereof, shall design and modify, reconstruct, relocate and rearrange or otherwise adjust tracks, bridges, telegraph, telephone and signal lines and other facilities of Railway and its tenants at the following locations, and following the completion of each item of said work Railway shall maintain said structures and facilities at its sole expense:

Item	*Mile Post*	*Description*

5. Work to be Performed by Public Authority at its Expense

Public Authority will, at its sole expense, operate, maintain, repair, renew, or in event of abandonment remove the flood control works located upon Railway's lands. If, in respect to any such work, the Railway Company renders any services or performs any work, Public Authority shall reimburse Railway promptly, for the cost thereof. The inspection of the flood control works, when completed and placed in operation, will not be the obligation or duty of Railway; however, in the event Railway should notify Public Authority of any unsafe conditions requiring repairs or renewals, and such repairs or renewals are not effected promptly, after notice to Public Authority so to do, Railway may, if it so elects, make such repairs or renewals and Public Authority shall reimburse Railway for the cost thereof, as hereinafter provided.

6. Prosecution of Work

The work to be undertaken and performed by Railway pursuant to the provisions of paragraphs 3 and 4 of this agreement shall be carried out according to a sequence of

Members of the Association who are interested in the tentative draft of agreement are requested to give the committee the benefit of their suggestion for its improvement.

FORM OF AGREEMENT FOR DIVISION OF WORK, MAINTENANCE AND OPERATION OF FLOOD PROTECTION PROJECTS

This Agreement, made this .... day of .... 19 ...., by and between .... hereinafter called Government, ... hereinafter called Public Authority and .... Railway Company, a corporation organized and existing under the laws of the State of .... hereinafter called Railway.

Witnesseth:

Whereas, pursuant to Act No. .... of the .... approved .... 19 .... which Act authorized construction of a flood control project located .... miles .... of ...., County, State of ...., and all appurtenant works under certain plans entitled ....; and

Whereas, said plans contemplate certain changes of existing facilities of Railway and its tenants, consisting of the following ....; and

Whereas, it is advantageous and in the best interest of Government and Public Authority to have Railway or its agents effect said changes; and

Whereas, said plans contemplate among other things the construction of earth levees, stop log closures, and other types of flood control works on Railway's lands and right of way, by Government or its agents; and

Whereas, Public Authority has agreed, upon completion of the project, to maintain and operate the flood control works in accordance with the regulations prescribed by Government; and

Whereas, Railway, or its agents, for the consideration hereinafter stated to be paid by Government to Railway, is agreeable to the changes in its tracks and facilities, all of which are shown on Railway drawing file .... dated .... 194 ...., attached hereto and made a part hereof, hereinafter referred to as Exhibit "A," and Railway is also agreeable to the operation and maintenance on Railway's premises of the flood control works by Public Authority under the conditions hereinafter set forth and at those locations shown on plan No. .... dated .... attached hereto and made a part hereof, hereinafter referred to as Exhibit "B."

Now, Therefore, in consideration of the covenants herein contained, the parties hereto mutually agree as follows:

1. Grant of Easement

Railway will, by separate formal instrument grant to Public Authority an easement in and upon such of the premises of Railway as may be required at the locations shown and described in said Exhibit B, but solely to the extent of the estate of Railway in said premises, for the construction, maintenance and use of new or improved flood control works to be located thereon incident to the provision by Government of said works. Each such grant will reserve in Railway, its successors and assigns, the right to retain, maintain and operate upon, along and across the premises covered thereby, the railway

of injury to or death of any person or persons, or damage to or destruction of property of any person whomsoever in connection with the maintenance and operation of the flood control works located upon premises of Railway.

10. Notification of Railway by Public Authority

In operating the flood control works covered by this agreement, Public Authority shall give notice to the operating superintendent of Railway or his authorized agent, when the water has reached an elevation of .... (Railway's datum), being .... inches below base of rail, of Public Authority's intent to start operation of any stop log closure structure when the water reaches an elevation of ....(Railway's datum).............. inches below base of rail, providing however, that operation of such stop log closures may be started before the water reaches an elevation of .... inch below base of rail, only upon written agreement between operating superintendent of Railway and Public Authority.

11. Government's and Public Authority's Agents Not To Interfere Unduly with Railways Operations

Government and Public Authority shall cause its contractors, agents, officers and employees engaged in the performance of any work on Railway's right of way to so conduct said work as to:

(1) Not unnecessarily or unduly interfere with any work being performed by employees or contractors of said Railway or the tenants and licensees of said Railway.

(2) Not interfere with the movement of trains or the use of any railway facilities, except as hereinbefore provided, and

(3) Not create any hazard to railway operations.

In Witness Whereof, the parties hereto have executed this Agreement in .... on the day and year first above written.

Witness:	.... Railway Company
....	By ....
Witness:	.... (Government)
....	By ....
Witness:	......................(Public Authority)
....	By ....

Report on Assignment 3

Form of Agreement for Railroad Force Account Work on Flood Control Projects

H. F. Brockett (chairman, subcommittee), J. P. Aaron, G. K. Davis, A. D. Duffie, L. J. Hughes, W. D. Kirkpatrick, J. S. Lillie, C. E. McCarty, A. A. Miller, W. L. Mogle, O. K. Morgan, C. B. Niehaus, J. L. Perrier, B. M. Stephens, J. L. Way, Clarence Young.

Last year your committee presented as information, a tentative draft of Form of Agreement for Railway Force Account on Flood Control Projects (Proceedings, Vol. 50, 1949, pages 258–263) and requested comments and criticism thereon. This form of agreement with revisions is now submitted with the recommendation that it be adopted and published in the Manual.

operations to be prepared by Railway and approved by Government. Each item of work shall be commenced as early as reasonably practicable after receipt of written notice from Government to proceed, and, subject to any delays in the completion of the work due to causes beyond the control of Railway, including but not restricted to, acts of God, or of the public enemy, acts of Government, acts of any contractor in the performance of a contract with Government, fires, floods, epidemics, quarantine restrictions, strikes, freight embargoes, and unusually severe weather or delays of subcontracts due to such causes, shall be prosecuted with diligence. If for any reason such notice to proceed with the work is not received before .... 19 .... then this agreement shall be null and void.

7. Payment for Work

Government shall pay on completion of work and Railway shall accept as payment in full for work performed by Railway, described in Article 4 herein, the lump sum of .... Dollars.

Public Authority shall reimburse Railway, for work performed by Railway, described in Article 5 herein, promptly after bills are rendered by Railway for such work. Bills rendered by Railway shall include wages, at the current rate paid by Railway for each class of labor furnished, including vacation allowance, Public Liability and Property Damage Insurance, Workmen's Compensation Insurance, Unemployment Compensation Insurance, payments pursuant to Social Security and Retirement laws, or similar laws, State and Federal, applicable to the work undertaken by Railway, and .... percent on labor costs for supervision and administration. Materials shall be billed at cost plus .... percent for handling, supervision and administration.

8. Insurance Provided by Government's and Public Authority's Contractors

For the protection of public agencies, Railway and other railways and utilities affected by said construction work, Government shall provide for procurement by its contractors and their sub-contractors of insurance. This insurance shall protect Railway and such other agencies, railways and utilities against loss or damage to property and against all claims, demands, suits or judgments arising because of, or resulting from the operation of said contractors, their subcontractors, agents or employees. Such insurance shall provide for payment for personal injuries not less than \$.............. for one person and \$.............. resulting from any one accident, and \$.............. for property damage for any one accident, with a total aggregate limit of \$.............. for property damage and shall be kept in effect by said contractor until all work contemplated herein, shall have been completed. All the policies must be written by companies qualified to write such insurance in the state in which the work is to be performed, and such companies must be acceptable to Railway. Certified copies of all policies shall be submitted to Railway for approval and it shall also be notified when the policies are cancelled.

In the event Public Authority elects to perform any of the work of inspection, maintenance, operation, repair, renewal or removal of the flood control works by contract it shall require its contractor or contractors and their subcontractors to provide Contractors Public Liability and Property Damage Insurance, for and in behalf of Railway Company, in amounts and under the conditions described in the preceding paragraph of this Article 8.

9. Railway Indemnified by Public Authority

Public Authority shall indemnify Railway, and save it harmless from all loss, claims, damages, costs, or causes of action of whatsoever nature, arising from or growing out

(a) All costs of surveys and preparation of plans, estimates, and specifications and expenses of inspection during the progress of the work, including wages, salaries and traveling expenses paid Railway employees (exclusive of general supervisory personnel) directly engaged in survey work, plan preparation and progress inspection, plus .... percent of such wages and salaries for supervision and administration.

(b) All costs arising under any subcontract for any portion of the work, provided said subcontract has been authorized by the Chief Engineer of Railway with approval of the Contracting Officer.

(c) All costs of labor furnished directly by Railway, including all wages, salaries and traveling expenses paid by Railway to its employees (exclusive of general supervisory personnel) engaged upon the work, plus .... percent of such labor costs for supervision and administration.

(d) All costs of materials furnished by Railway plus stores expense at the rate of .... percent of the value of materials furnished by Railway's stores department and purchase expense at the rate of .... percent on the cost of materials furnished through Railway's Purchasing Agent, for handling, supervision and administration.

(e) All costs of Workmen's Compensation or Employers' Liability Insurance and Federal Employers' Liability, Fire Insurance, Public Liability, Owner's and Contractor's Contingent Liability and Property Damage Insurance.

(f) All applicable taxes levied on any materials purchased for the work.

(g) Rental on tools, equipment, and machinery (including locomotives and work trains), rolling stock and roadway machines furnished by Railway at rental rates set up in General Managers' agreement.

(h) Cost of bond premiums and cost of fees for all permits and licenses.

(i) Vacation allowances and all taxes, federal and state, based on compensation paid by Railway to employees engaged upon the work.

(j) Cost of transportation of materials and equipment over Railway's lines at .... mills per ton-mile and at actual cost for other transportation.

(k) Such other items of expense as may be agreed upon by the Contracting Officer and the Chief Engineer of Railway.

Government shall reimburse Railway monthly upon receipt of properly certified invoices in *(number of copies)* approved by the Contracting Officer.

Upon completion and final acceptance of all work performed by Railway and within .... days following receipt of certified invoices, Government shall make final payment to Railway.

Railway shall furnish such evidence as may be required of it and shall permit examination of its records from which invoices have been prepared.

4. Changes during Construction

Subject to the approval of the other, either the Contracting Officer or the Chief Engineer of Railway may, by written order, make changes in the plans and specifications of this agreement and within the general scope thereof. If such changes cause an increase or decrease in the amount due under this agreement, or in the time required for its performance, an equitable adjustment shall be made and this agreement shall be modified in writing accordingly.

FORM OF AGREEMENT FOR RAILWAY FORCE ACCOUNT WORK ON FLOOD CONTROL PROJECTS

THIS AGREEMENT, entered into this .... day of .... 19 ...., by and between the United States of America, hereinafter referred to as "Government" represented by the Contracting Officer executing this agreement and .... a corporation organized and existing under the laws of the State of ...., hereinafter referred to as "Railway" having its principal office at ....

WITNESSETH:

WHEREAS, pursuant to Act No. .... of the ....th Congress of the United States of America approved ...., 19 ...., which Act authorized construction of a flood control project located .... miles ....(direction)........ of ....(Town or City)........, ... County, State of ...., and all appurtenant works under certain plans entitled ....; and

WHEREAS, said plans contemplate certain changes of existing facilities of Railway and its tenants, consisting of the following: ....; and

WHEREAS, it is advantageous and in the best interest of Government to have Railway or its agents, effect said changes; and

WHEREAS, Railway, for the consideration hereinafter stated, is agreeable to the changes in its tracks and facilities, as shown on Railway drawing, file ...., dated .... 19 ...., attached hereto and made a part hereof, hereinafter referred to as Exhibit "A."

NOW, THEREFORE, in consideration of the covenants herein contained, the parties hereto mutually agree as follows:

1. Scope of Work

(a) The work to be performed by Government within the scope of this agreement is substantially as shown on plans and described in specifications approved by the Contracting Officer and the Chief Engineer of Railway.

(b) The work to be performed by Railway within the scope of this agreement is substantially as shown on Exhibit "A," and includes but is not limited to, the following:

....
....
....

2. Prosecution of Work

Railway will begin work promptly after receipt of notice to proceed, and will complete the work within .... months after receipt of such notice, subject to delays due to causes beyond its control. If for any reason such notice to proceed with the work is not received before .... 19 ...., then this agreement shall be null and void.

3. Payment for Work

Government shall reimburse Railway for the cost of all work performed and materials furnished by Railway. The costs shall include all items of expense properly chargeable to the work, including the following:

9. Right of Way

Government shall convey or cause to be conveyed to Railway, without cost to Railway, and before start of work, good merchantable title, free and clear of liens and encumbrances, to such right-of-way, lands and property as may be required by Railway for its new roadbed, slopes, berms, drainage, communication lines, and other facilities.

10. Approval

This agreement shall be subject to the written approval of the Chief of Engineers, Department of the Army, Washington, D. C., and shall not be binding until so approved.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in........... as of the day and year first above written.

THE UNITED STATES OF AMERICA
By ....
Title ....

Witnesses: ....COMPANY
.... By ....
.... Title ....

5. Disputes and Arbitration

Except as otherwise provided, all disputes concerning questions of fact arising under this agreement shall be decided by the Contracting Officer and the Chief Engineer of Railway.

In case any question arises under this agreement or concerning the subject matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the judge of the .... Court of .... The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

6. Licenses and Permits

Railway shall obtain all required licenses or permits from the Interstate Commerce Commission, state or local authorities for prosecution of the work.

7. Insurance

Before performing any work Railway shall arrange for and procure the following insurance coverage and shall keep the same in effect until the work is completed and accepted:

(a) Fire insurance to cover structures, and structural materials and supplies on hand owned by Railway or its subcontractors which may be subject to damage as a result of fire.

(b) Workmen's Compensation or Employers' Liability Insurance and Federal Employers' Liability Insurance covering employees of Railway, and Workmen's Compensation covering employees of its subcontractors, as required by the state in which the work is to be performed, so that Railway and its subcontractors shall be fully protected from any liability or claim for damages for personal injury, including death, suffered by such employees, which may arise while Railway is engaged upon the work covered by this agreement.

(c) Public Liability Insurance providing limits of $................ per person and, subject to the same limits per person, $................ per accident; and Property Damage Insurance providing a limit of $................ per accident with an aggregate limit for the policy of $.............. Government shall be shown as an additional insured.

(d) If there are one or more subcontractors, Protective Public Liability and Property Damage Insurance in the same amounts as required in paragraph (c) above.

All the policies must be written by companies qualified to write such insurance in the state in which the work is to be performed, and such companies must be acceptable to the Contracting Officer. Certified copies of all policies shall be submitted to the Contracting Officer for approval and he shall also be notified when the policies are cancelled.

8. Final Inspection

Railway shall notify the Contracting Officer promptly upon completion of the work. The Contracting Officer or his authorized representative shall make final inspection within .... days from the receipt of notice of completion and the Contracting Officer, if the work is satisfactory, shall notify Railway of his acceptance.

Report on Assignment 2

Classification Yards, Collaborating with Committee 16

B. Laubenfels (chairman, subcommittee), F. E. Austerman, E. G. Brisbin, W. O. Bruce, J. C. Bussey, K. L. Clark, Oscar Fischer, H. C. Forman, W. H. Giles, H. J. Gordon, E. E. Hammond, H. H. Harsh, W. W. Hay, F. A. Hess, J. L. Loida, L. L. Lyford, J. L. Perrier, C. M. Ratliff.

Your committee presents as information the following report pertaining to classification yards entitled "Design of Flat Switching Yards."

The various designs of flat yards result from local factors such as topography, the proximity of other railway facilities, the number and length of tracks required and operating conditions. However, the number of different layouts may be reduced to a relatively few basic designs, the most common of which are illustrated in Fig. 1. These are described briefly as follows, the paragraph numbers corresponding to numbers shown in Fig. 1.

1. Ladders at each end of yard, nonparallel, with all turnouts in ladders. In this layout no two tracks are the same length.
2. Ladders at each end of yard, parallel, with all turnouts in ladders. In this layout all tracks are the same length.
3. Two diverging ladders with single drill track at each end of yard.
4. Two diverging ladders with independent drill tracks and opposing crossovers at each end of track. (Where necessary scissors crossovers may be substituted for opposing crossovers).
5. Two converging ladders with independent drill tracks at each end of the yard. This is an unusual arrangement.
6. Two parallel adjacent ladders with independent drill tracks and opposing crossovers at each end of the yard. This is an unusual arrangement.
7. Separate groups of body tracks connected to independent parallel ladders (one ladder being in advance of the other) with an independent drill track for each ladder at each end of yard. A crossover at each end of the yard connects the drill tracks.
8. Ladders at ends of yard, nonparallel, with alternate turnouts in body tracks, using long connecting rods and with all switch stands outside of ladder. (If tracks of same length are desired parallel ladders can be used with the same turnout and switch stand arrangement).

Auxiliary drill tracks may be connected to the single ladders at each end of a yard to divide the yard into groups of tracks. This requires the connection of some body tracks to adjoining body tracks to make room for auxiliary drill track turnouts in the ladder.

In designing flat yards consideration should be given to the following:

(a) Running or open track adjacent to the drill track to permit by-passing.
(b) Advantages and disadvantages of right-hand and left-hand ladders.
(c) Sight distance of enginemen on drill and ladder tracks.
(d) Assisting gradients on drills, ladders and body tracks.
(e) Number of cars in the cut to be classified by switch engine.
(f) Angle and length of the ladder track.

Report of Committee 14—Yards and Terminals

W. H. GILES, *Chairman,*	E. E. HAMMOND	J. E. HOVING, *Vice-Chairman,*
M. H. ALDRICH	M. J. J. HARRISON	C. H. MOTTIER
C. J. ASTRUE	H. H. HARSH	J. E. NEWSOM, JR.
F. E. AUSTERMAN	W. H. HARTMAN	B. G. PACKARD
C. A. BEGGS	D. C. HASTINGS	C. F. PARVIN
A. E. BIERMANN	E. M. HASTINGS	J. L. PERRIER
W. O. BOESSNECK	F. M. HAWTHORNE	C. M. RATLIFF
E. G. BRISBIN	W. W. HAY	H. T. ROEBUCK
W. S. BROOME	W. J. HEDLEY	W. B. RUDD
N. C. L. BROWN	H. W. HEM	W. C. SADLER
W. O. BRUCE	F. A. HESS	G. A. SARGENT, JR.
H. F. BURCH	W. H. HOBBS	J. W. SELTZER
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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.
2. Classification yards, collaborating with Committee 16.
   Progress report, presented as information .... page 179
3. Scales used in railway service.
   No report.
4. Bibliography on subjects pertaining to yards and terminals.
   Progress report, presented as information .... page 181
5. Locomotive terminal facilities.
   No report.
6. Facilities for mechanical handling of l.c.l. freight, collaborating with Committee 6.
   Final report, presented as information .... page 184
7. Relative advantages and physical factors to be considered in the design and selection of flat, gravity or hump yards for handling various volumes and kinds of traffic.
   Final report, presented as information .... page 187
8. Design of track layout and gradients in connection with scales located on the hump of a classification yard.
   Final report, presented as information .... page 190
9. Factors to be considered in determining the location of a track scale in a yard.
   No report.
10. Recent developments in under-car inspection of freight cars.
    Final report, presented as information .... page 192

THE COMMITTEE ON YARDS AND TERMINALS,
W. H. GILES, *Chairman.*

AREA Bulletin 483, November 1949.

Report on Assignment 4

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W. C. Sadler (chairman, subcommittee), C. J. Astrue, W. O. Bruce, W. H. Goold, W. W. Hay, R. A. Sharood.

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Passenger Stations and Terminals

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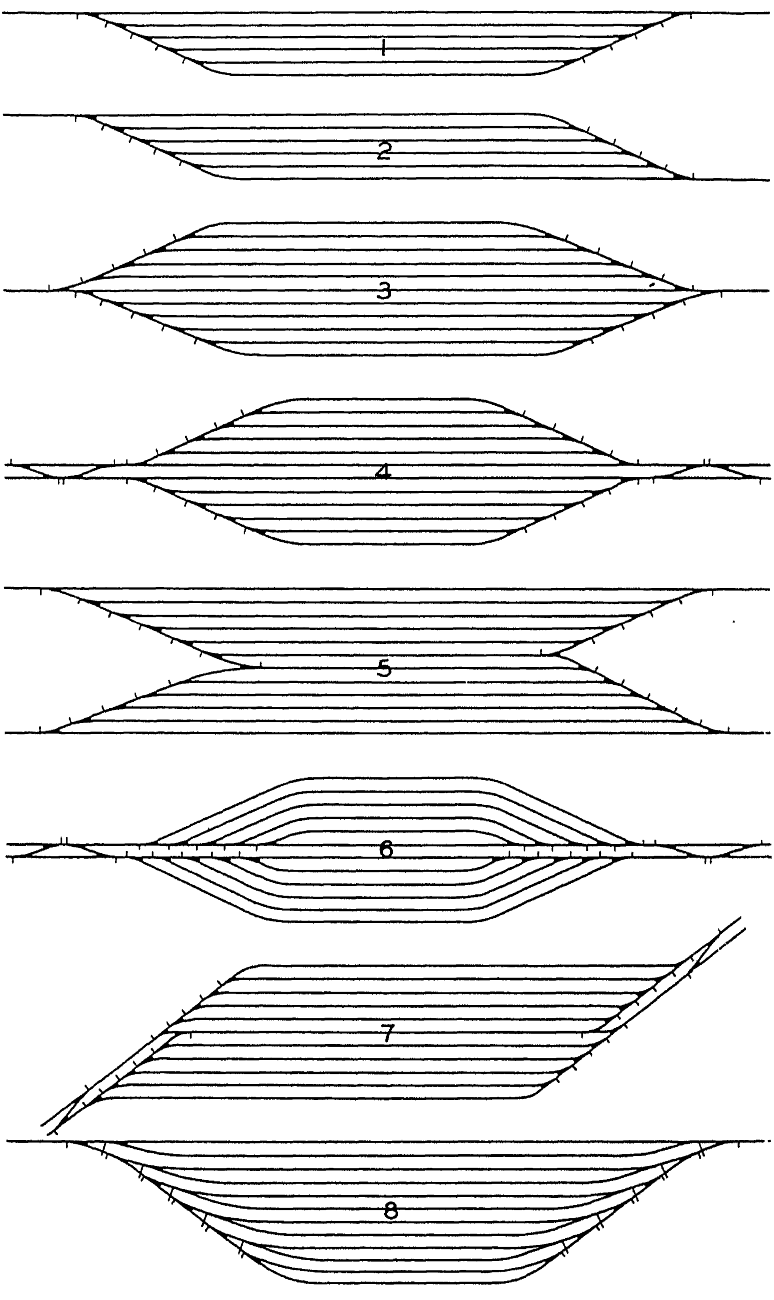

Fig. 1.—Flat Yards with Various Arrangements for Ladder and Drill Tracks.

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Station mechanization continues*—Railway Age 126:1040–1, May 21, 1949.

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2. Trailer—33,719

Platform trucks (usually four wheels) on which freight is loaded and moved by hand or tractor to freight car, platform or motor truck. As many as 20 loaded trailers are handled by a tractor at one time thereby expediting the movement of freight through freight houses.

3. Fork Lift Truck or Tiering Truck—496

A four-wheel hand-operated, gasoline or electric powered device equipped in front with movable forks, used for loading or unloading heavy and bulk articles. The forks are slid under the load (or under pallet if load is palletized), and the load is then raised off the floor and moved directly to car, platform or truck. This truck can be used also for stacking palletized or uniformly packaged shipments. It is particularly well adapted to handling of shipments in locations where platform or freight house floor space is limited as its ability to pile shipments to a fairly high level permits maximum use of available floor space.

4. Low-Lift Hand Truck—150

A low platform or fork-type power truck which can be placed under a pallet or skid after which the load is raised by pumping a handle, foot pedal or lever, raising the load off the floor, permitting free movement. The advantage of this type of equipment is that it provides an economical means of handling heavy shipments in crates or on skids or pallets. This device takes the place of rollers and bars.

5. Low-Lift Power Truck—86

A low-platform or fork-type power truck which can be placed under a pallet or skid after which load is raised off floor. One man operates it by walking in front of and steering with the handle. Used in the movement of freight on pallets.

6. Three-Wheel Platform Truck—358

A three-wheel gasoline powered pneumatic-tired platform truck, operated by one man who rides with the freight. Maneuvers easily because of very short turning radius. It is particularly adaptable to large stations where freight is moved a maximum distance.

7. Power Operated Crane Truck—19

Some are equipped with telescopic boom. For loading and unloading beams, pipe and heavy articles of unusual size when handled in volume.

8. Electric Mono Rail Hoist—3

A motor driven wire rope hoist, suspended by four roller or gear wheels, or a combination of roller and gear wheels, from an overhead monorail which spans the area over which freight is to be handled. The monorail is usually an I-beam, and the suspension wheels bear upon and roll along the bottom flange. The movement may be either power or manually operated. The hoist is operated through push-button control.

9. Chain Hoist—9

Hand operated portable chain hoist suspended by hook or other device. Used for hoisting and lowering heavy material. Increases speed and reduces cost of handling.

10. Two-Wheel, Hydraulic Lift Hand Truck (Twin Unit)—117

A two-unit hydraulically operated device on small wheels under full swivel casters, with short protruding lips or forks, used for moving large bulky awkward crated or

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Report on Assignment 6

Facilities for Mechanical Handling of L. C. L. Freight, Collaborating with Committee 6—Buildings

W. O. Boessneck (chairman, subcommittee), H. F. Burch, W. H. Giles, F. M. Hawthorne, W. J. Hedley, W. H. Hobbs, A. S. Krefting, J. H. Lindsay, C. H. Mottier, J. F. Newsom, Jr., J. L. Perrier, W. C. Sadler, G. A. Sargent, Jr., H. W. Smith, C. F. Worden.

In 1948 a report was submitted under the title Facilities for Conveyor handling of L.C.L. Freight at Freight Houses and the general subject Facilities for Mechanical Handling of L.C.L. Freight has been studied further under the present assignment. This report covers facilities other than fixed conveyors that are used by railroads in handling l.c.l. freight and is presented as information.

It has been stated that in 1906 a railroad in the United States mounted an electric motor on a baggage wagon and thus created the first power-operated truck which greatly improved the handling of freight shipments both by railroads and shippers. As the use of this truck has grown, the use of the hand truck has decreased but the hand truck has been improved with such changes as rubber tires, roller bearings and special designs for specific purposes.

Early mechanization in freight house equipment was the tractor-trailer train, with the objective of eliminating manual handling and speeding up operations. During World War II the fork lift or tiering truck came into greater use in an endeavor to offset the acute manpower shortage. Today such trucks are in common use and their advantages are further increased by the application of the "unit load" principle. (A unit load includes a number of smaller loads so put together that they can be handled at one time by a machine.) In addition to greatly reduced costs by such handling, substantial savings are made in loss and damage to freight. Pallets and palletized containers are no longer a novelty in freight houses.

For the purpose of determining the various types of mechanized equipment now commonly used by the railroads, the quantity of each type used and a general description, a letter canvass was made of the railroads represented on Committee 14 and certain other railroads. Of the 36 railroads addressed, 28, operating in United States, Canada and Alaska, submitted replies. The following statement lists the total number of pieces of each type of equipment most commonly used by the railroads that replied, and includes a brief description and comments on each device.

1. Electric or Gasoline Tractor—682

Gasoline or electrically powered, used for pulling loaded trailers or live skids in tractor-trailer operation. Particularly desirable when freight is to be moved in volume for long distances.

Other equipment and facilities reported were ramps, elevators, power sweepers, communication systems, car movers, door openers, gang-planks, cargo-tainers, bulkheads, steel strapping tools and various pry bars.

To properly accommodate and obtain maximum benefits from the use of mechanized equipment in new or modernized freight houses certain features must be given special consideration because their requirements differ from those for nonmechanized freight houses. This applies particularly to the floors, passageways, platforms, ramps, gangplanks, headroom, fender protection and elimination of columns.

The floors should be of adequate strength to support the loaded, moving equipment. Consideration should be given to equipping vehicles with rubber tires to eliminate noise and excessive wear of floors.

Repair and servicing facilities are required to properly care for the mechanical equipment.

The above special considerations are stated in general terms. The types of freight to be handled and mechanized equipment to be used will influence these features and therefore each freight house should be studied and designed according to its needs.

Each type of equipment has its own particular advantage over another type because it fits a special requirement at one definite location and the decision as to the type of equipment needed must be based on the needs and operation at any location.

Report on Assignment 7

Relative Advantages and Physical Factors to be Considered in the Design and Selection of Flat, Gravity or Hump Yards for Handling Various Volumes and Kinds of Traffic

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This is a final report presented as information.

The Manual definitions for the three types of yards mentioned in this assignment are as follows:

> Flat Yard: A yard in which the movement of cars is accomplished by a locomotive without material assistance from gravity.
>
> Gravity Yard: A yard in which the classification of cars is accomplished by a locomotive with the material assistance of gravity.
>
> Hump Yard: A yard in which the classification of cars is accomplished by pushing them over a summit beyond which they run by gravity.

Inasmuch as, in practice, there is no distinct dividing line between flat and gravity yards, this report will consider these two types as combined and they will be referred to hereinafter as "flat yards."

This assignment relates to design as well as selection of the type of yard. Design is a very broad subject, on which much detailed material has previously been submitted by Committee 14. This report, therefore, will deal only with volume and kind of traffic and physical factors which influence the selection and design of the type of yard best suited to a given set of conditions.

A

uncrated shipments, etc. One unit is placed at each end of the load, a small handle is pumped which raises the load off the floor permitting free movement manually.

11. Portable Gravity Roller Conveyor—56

Portable and constructed in sections, straight and curved which can be coupled together and mounted on adjustable or nonadjustable supports. This equipment is especially suitable for handling freight from one level to another.

12. Hydraulic Pallet Jack—22

A one-man operated hydraulic jack on wheels, used for raising the "skid end" of semi-live skids, thus placing entire load on wheels for free movement.

13. Miscellaneous Jacks—174

Reported as lift jacks, auto jacks, stone jacks, car jacks, track jacks and vertical lift jacks.

14. Miscellaneous Cranes and Derricks—26

Stationary crane, overhead hand crane for transferring heavy loads from trucks to platform and vice versa, gantry cranes, portable crane with U-base, stiff leg cranes electrically operated, electric gantry cranes, stiff leg derrick.

15. Miscellaneous Trucks—65

Trucks especially equipped to handle particular articles such as pianos, glass, bulky materials and crates.

16. Pallet—23,132

A platform of wood or other light material with deck boards at the top and bottom and space between for the entry of forks of lift trucks, on which freight is loaded and picked up with fork lift trucks or hand lift trucks. Size varies, generally about 48 in. by 48 in.

17. Two-Wheel Hand Truck—8205

A small device with one or two handles and protruding ledge which can be slipped under load, after which operator bears down on the handle to the wheeling position. It is used for moving barrels and small heavy articles. Many are equipped with roller bearings and rubber tires. Railroads find this to be an efficient means for handling freight, particularly in highly congested freight houses and platforms and where the distances to be traversed are short.

18. Skids—202

Skid—A low platform equipped with four small runners.

Semi-Live Skid.—A low platform equipped with two small runners on one end and two wheels on the other.

19. Microlever Dolly—40

A two-wheel pry device, with metal toe, for lifting heavy articles to place rollers under it.

Other Facilities

Motorized lift bridges and retractable trucking tables are used to bridge tracks between freight house platforms.

one for assembling, when the volume nears 1500 cars. This applies whether the volume represents traffic in one direction only or the combined traffic in both directions.

D. Volume Exceeding 2000 Cars

1. A single hump retarder yard is preferable for this volume of traffic. At least two engines per shift are needed, one for humping and one for assembling cars. However, additional engines per shift may be needed as the volume increases. Maximum capacity is attained by using two engines for humping and two or more engines for assembling. This applies whether the volume represents traffic in one direction only or the combined traffic in both directions. If trains are forwarded directly from the classification yard, extra leads and running tracks are needed to avoid interference.

2. There are a number of single hump retarder yards which have handled nearly 4000 cars in 24 hours, but there are few which have handled more than an average of 3000 cars in 24 hours for any extended period. When the volume of traffic for any extended period exceeds the average of 3000 cars, a second or auxiliary yard should be considered. Where the indicated excess over that which a single hump yard will handle is small, the excess as a rule occurs only at short intervals during peak periods and it could be handled with some supplementary flat yard switching, in which case a small auxiliary flat yard, such as described in "A" or "B," may be considered advisable.

3. When the volume of traffic handled exceeds appreciably, and for extended periods, that which can be handled in a single hump retarder yard, consideration should be given to providing two separate hump yards of this type, one for handling traffic in each direction.

Other Factors

Detail study must be given to a project and the design, based on volume, must be modified to satisfy the other factors. Some of these other factors are:

1. Faster switching is often required to expedite the movement of scheduled trains, perishable goods, etc., thus requiring facilities capable of handling the traffic within a minimum period of time.

2. Arrivals may be concentrated within one or two shifts and thus require a more rapid rate of switching.

3. Interference, which cannot be avoided by the design of the facilities, can limit the speed of operation sufficiently to require additional capacity.

4. Relation between length of trains and receiving or departure tracks is a factor of interference.

5. The number of cars that can be brought to the hump at one time affects the capacity of a hump.

6. Whether trains depart from the classification yard or from a separate departure yard affects the time of assembling trains.

7. Tracks for handling road engines to and from their trains.

Selection

Due to the wide variations in the requirements at specific locations, no definite rule can be laid down as to the best type of yard for a certain set of conditions. The economics of each specific location must be studied and duly considered before selecting the type of yard. To make such a study, the following procedure is suggested:

Of the three major functions of a yard—receiving, classifying and forwarding—only the classification function influences the selection of type, either flat or hump. In any case, receiving and departure tracks must be provided in sufficient number and capacity to handle the traffic through the yard.

Volume of Traffic

Traffic volume should be considered as the daily average number of cars handled. single count, during an extended period. Where a new yard, or the reconstruction of an existing yard is contemplated, a check should be made of the record of cars handled, taking into account the possibility of transferring switching from other yards.

There is a purpose for each type of yard depending upon the volume and character of traffic. The following types of yards, with relation to various volumes of traffic, are intended only as a general guide. The number of cuts and cars per cut materially affect the capacity of the yard.

A. Volume up to 500 Cars

A flat yard with a ladder and drill track at each end is adequate regardless of the number of classifications to be made or number or cars per separation or cut.

B. Volume of 500 to 1000 Cars

1. A flat yard with ladder and drill track at each end may be adequate, if the number of classifications to be made are nearly equal to the number of tracks in the yard and assuming two engines per shift are needed, one working each end of the yard, to attain the maximum capacity.

2. A flat yard with two ladder tracks and one drill track at each end may be needed where the number of classifications exceed those which can be switched from one ladder. Two engines per shift, one working on each end of the yard, are needed to attain maximum capacity.

3. A single hump retarder yard may be preferable for the handling of traffic in one or both directions, if the number of cars per separation is small and the number of classification is large. One engine per shift may be ample for classifying and assembling cars.

This arrangement is of particular advantage at a location where there is interchange with other railroads or where industries are served, because trains from either direction will have cars which should be assembled for delivery; also, transfers will have cars moving in either direction.

C. Volume of 1000 to 2000 Cars

1. A flat yard with a ladder and drill track at each end may be adequate; if the number of classifications to be made is nearly equal to the number of tracks in the yard and if there is a large number of cars per separation. For maximum capacity, two engines per shift are needed.

2. A flat yard with two ladder and drill tracks at each end may be needed where the number of classifications exceeds that which could be handled in C–1. Four engines per shift may be needed to attain maximum capacity.

3. A single hump retarder yard may be needed where the number of classifications is large and where there is a small number of cars per separation. One engine per shift is adequate for both switching and assembling when the volume is near 1000 cars, but two engines per shift are needed, one for switching and

Dead rails should be provided for all scales not designed to support the heaviest locomotives likely to run over the weigh rails. It may be desirable to provide dead rails regardless of the design of the scale, since a scale without them is a source of increased maintenance. Weigh rails should be on the straight line, and the dead rails on the offset line.

Gradients Required for Spot Weighing

The gradients required for a scale on the hump where spot weighing is done present no problem. It seems, however, that spot weighing on the hump defeats the purpose of installing such a scale. The use of motion weighing is highly desirable.

If possible the gradients for motion weighing must be designed so as to permit weighing without limiting the speed of humping. The gradients selected must be designed to provide the proper separation of cars above the scale, the proper time on the scale, and the desired increase in velocity below the scale for movement to any classification track. The following factors have to be considered in order to develop the proper gradient—

1. Maximum and minimum length of car to be weighed
2. Maximum humping speed during weighing
3. Types of lading handled
4. Temperature and prevailing winds
5. Conditions affecting rolling friction of cars.

The gradient and the distance from the apex of the hump to the scale must be such as to give proper separation of cars for weighing, and must be so related to the length of scale, the gradient of the weigh rails, and the types of cars to be weighed that a minimum weighing time of 4 sec. per car will be secured for free running cars. The approach to the scale for at least 10 ft. should be on the same gradient as the weigh rails so as to prevent the car from coming on to the scales surging on the springs.

The gradient across the scales should not exceed one percent and must be such that the minimum weighing time of four seconds per car is secured.

The gradients below the scale should conform to the AREA recommendations for the type of yard (See Proceedings, Vol. 33, 1932, pp. 114 and 115) and they are a separate and distinct problem in themselves. The point at which the cars leave the weigh rail grade should be considered for design purposes as a secondary apex. When the initial speed is calculated at this point, then the design should proceed from that elevation to the elevation at the lower end of the yard and the necessary intermediate gradients should be designed to assure that all cars will travel to the required points with the necessary manual or mechanical retardation for proper movement to clear all tracks.

Relation of Gradient to Scale Length

In many cases the selection of a scale length is influenced by railroad standards. The length of scale may be a rather critical point in the design of the gradients if short and long cars are to be weighed mixed in a train. The maximum speed across the scale to satisfy the four-second requirement will be;

$$\frac{\text{Scale length} - \text{extreme wheel base of longest car}}{4} = \text{feet per second}$$

This speed should fall somewhere in the range of 4 to 6 mph., and this is above normal humping speed. To attain the required separation for motion weighing it is necessary

1. Develop a plan and an estimate of the initial and operating costs for a flat yard to handle the anticipated volume of traffic.
2. Develop a plan and an estimate of the initial and operating costs for a hump yard with retarders under the same conditions.

Related facilities to be considered in developing these plans and estimates are the following.

a. Future expansion.
b. Icing of cars both bunker and body.
c. Stock handling facilities.
d. Bad order tracks and car repair facilities.
e. Car inspection (facilities to be provided if moving inspection is to be made).
f. Weighing facilities.
g. Lighting system.
h. Communication and signaling.
i. Drainage.
j. Engine routing.
k. Engine servicing facilities.
l. Hold tracks.

Report on Assignment 8

Design of the Track Layout and Gradients in Connection with Scales Located on the Hump of a Classification Yard

D. C. Hastings (chairman, subcommittee), M. H. Aldrich, C. A. Beggs, W. S. Broome, N. C. L. Brown, J. C. Bussey, W. H. Goold, H. J. Gordon, J. E. Griffith, M. J. J. Harrison, F. A. Hess, A. S. Krefting, E. K. Lawrence, J. H. Lindsay, L. L. Lyford, H. T. Roebuck, W. B. Rudd. J. W. Seltzer, J. W. Wiggins.

This is a final report presented as information.

A scale on the hump may be located on the main lead or leads or on an auxiliary lead. In designing the track layout and the gradients for a scale so located, each location will present problems and the question will be one of a complete design for each. Certain fundamentals are common to all installations and should be considered in the design.

The Track Layout

The track layout should be such that all tracks leading from the receiving yard to the hump will connect into the main hump lead or leads, and into a track by-passing the hump for the use of road locomotives and other movements. In the event the scale is located on an auxiliary hump lead this track should be accessible from all receiving yard tracks and should lead into all classification yard tracks to avoid extra handling. This auxiliary hump lead has the undesirable feature of lengthening the hump layout. If operating conditions require the use of two leads across the hump, consideration should be given to installing a scale on each lead. The track layout, however, should provide double crossovers both ahead and beyond the scale location regardless of whether or not two scales are installed. The economics of operation as compared to the cost of installation will be an important feature in the choice of installing one or two scales on a double lead hump. At many locations where the classification tracks are so designed as to allow simultaneous humping and the majority of the cars are to be weighed, two scales are justified.

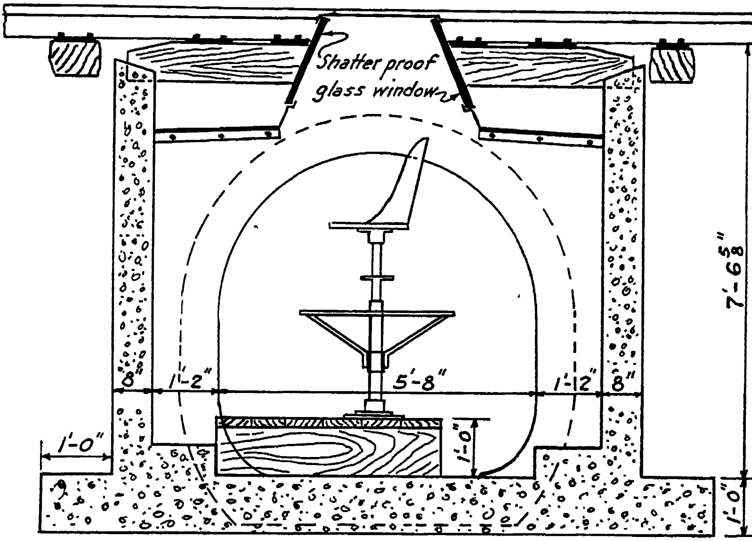

Fig. 1.—Cross Section of Precast Pit.

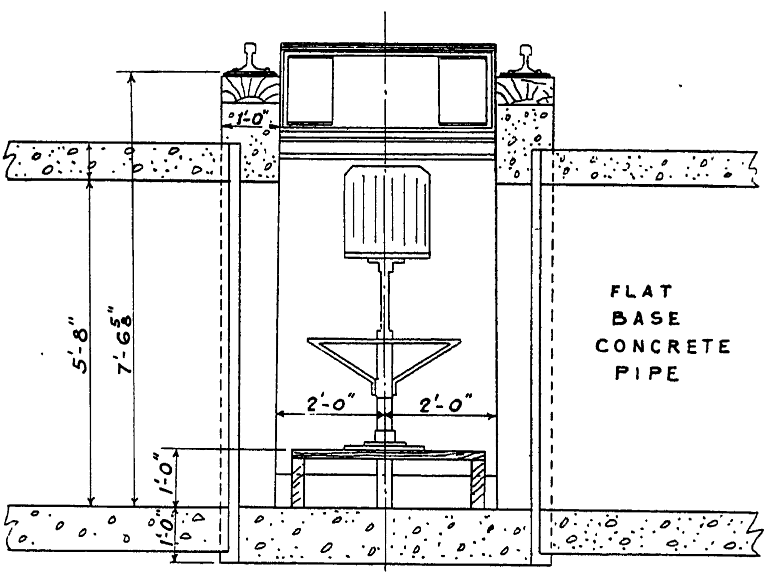

Fig. 2.—Transverse Section of Precast Pit.

that the lead wheels of the car ahead leave the scale before the lead wheels of the car to be weighed reach the beginning of the scale. Thus the minimum separation requirements will be a speed at the scale of

$$\frac{\text{Humping speed} \times \text{scale length}}{\text{coupled length of car}} = \text{feet per second}$$

Obviously to handle long and short cars together these speeds at the scale must be compatible. If they are not then either the humping speed or the length assumptions of the cars must be modified until both the requirement for scale time and separation can be satisfied. In cases where long cars are infrequent, then to achieve the desired scale time for the long car it may be desirable to design with reductions in the humping speed to handle the occasional car of unusual length.

The gradients of the track ahead of the scale, or combinations of gradients and a retarder must be arranged to provide the velocity required by the above equations.

In general the most desirable solution is to arrange the track layout and gradients so as to place the scale as close to the apex of the hump as possible to achieve the requirements or proper separation and weighing speed and then proceed below the scale to design a layout and system of gradients to meet the requirements of the classification yard.

Report on Assignment 10

Recent Developments in Under-Car Inspection of Freight Cars

A. E. Biermann (chairman, subcommittee), C. J. Astrue, F. E. Austerman, W. S. Broome, W. O. Bruce, H. C. Forman, W. H. Giles, H. J. Gordon, W. N. Hartman, F. M. Hawthorne, B. Laubenfels, C. E. Merriman, C. H. Mottier, C. F. Parvin, H. T. Roebuck, G. A. Sargent, Jr., J. W. Seltzer, C. F. Worden

This is a final report presented as information.

A pit used for the purpose of inspecting the underside of freight cars in motion had its origin on the Pennsylvania Railroad in 1929 and the results achieved from the use of this pit were such that this railroad has constructed 11 additional units. Following the Pennsylvania's installation, the New York Central Railroad, and the Richmond, Fredericksburg & Potomac Railroad built facilities using similar pits.

The pit units, sections of which are shown in Figs. 1 and 2, are located in advance of the crest of the hump and are of precast concrete construction. The connecting passageway between double track pit facilities is flat base concrete pipe, as the sides of the precast pit have an opening corresponding to the cross section of a 68-in. by 68-in. flat base concrete pipe.

In 1934 the Chesapeake & Ohio Railway built inspection facilities consisting of double-pit installations at two locations. These pits and connecting passageways are constructed of reinforced concrete with concrete encased steel beams to carry the rail load. The pits are 5 ft. long and 3 ft. 7-5/32 in. wide on the inside. At one installation the pit floor is 8 ft. 1½ in. below base of rail and at the other 7 ft. 2 in., the connecting passageway between the two pits at both installations being a rectangular concrete box.

The roofs of the previously mentioned pits consist of a steel hood, incorporating two inclined panels or windows of shatterproof glass, one facing in each direction. Immediately in front of each window is a depressed area in which flood lights are mounted to illuminate the underside of the cars. Swivel chairs mounted on wood platforms are

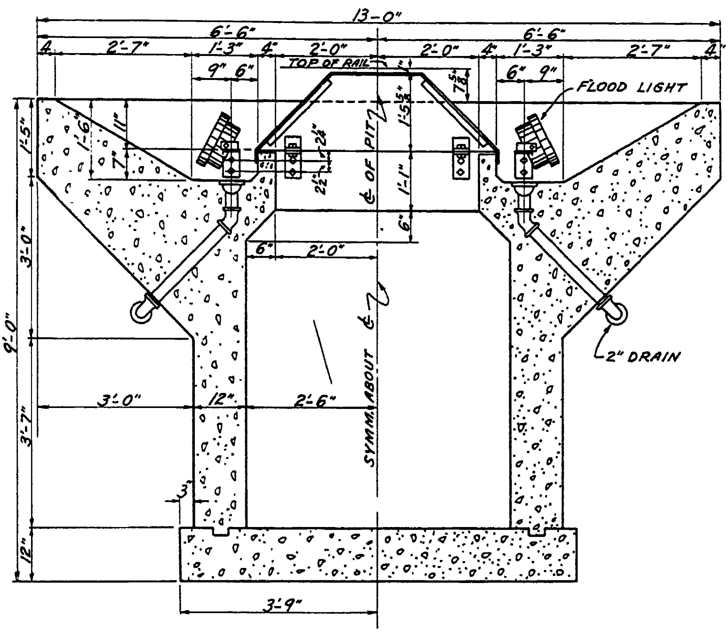

Fig. 4.—Cross Section of Union Pacific Pit.

pits and two elevated platforms with all inspection positions enclosed. This under-car pit is in reality a portion of a reinforced concrete passageway which runs under the hump track. The rail load is carried over the pit by reinforced concrete beams and the roof of this pit is a steel hood with glass windows. A depressed area at each end of the hood provides mounting space for flood lights. A swivel chair is mounted in the pit on an adjustable steel column.

In advance of the under-car pit station are two side inspection pits 8 ft. 3 in. long built integrally with the passageway, one on the outside of each rail. The inside of the front wall of these pits is 6 ft. 1½ in. from the center line of the track, and the tops of the reinforced concrete walls are at base of rail. A steel hood 3 ft. wide at the base, 1 ft. 7¾ in. wide at the top, 3 ft. 4 in. high and 8 ft. 8¾ in. long is mounted flush on the front wall and parts of the side walls. The hood has a fixed shatter-proof glass window in each end and one hinged and two fixed shatter-proof glass windows in the inclined front wall.

Between each pit and the near rail an inclined mirror 2 ft. wide and 8 ft. long is installed with one edge of the mirror at and slightly below the top of rail. These mirrors are used by the inspectors to gain better vision of the underside of the cars. A vertical ladder from the passageway floor provides access to these pits. Adjacent to the side pits and extending over the passageway is a welded steel frame enclosed tower 16 ft. long. A wood platform is located 11 ft. 2 in. above base of rail and is reached by an interior vertical steel ladder from the passageway floor. On the track side of each

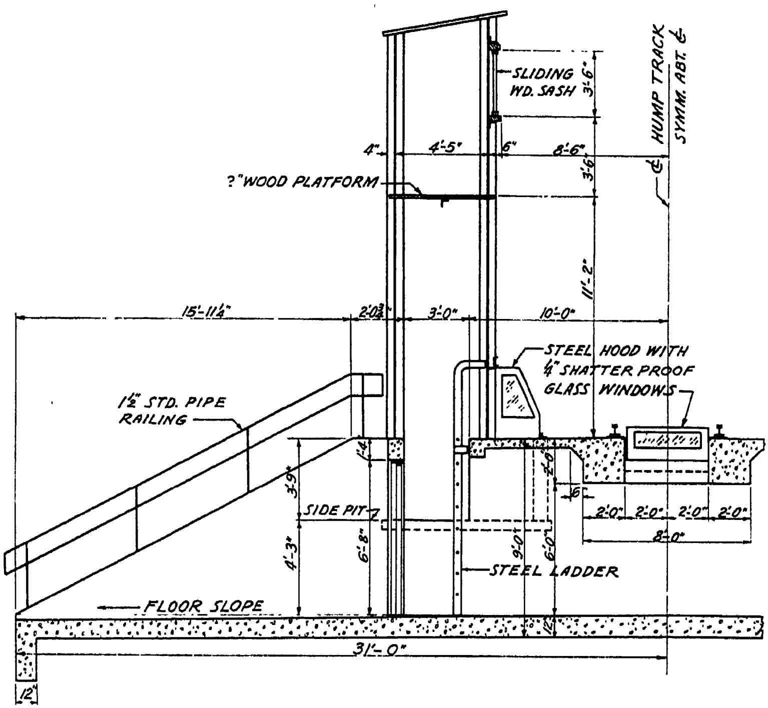

Fig. 3.—Transverse Section of Union Pacific Pit.

used by the car inspectors. Air pressure whitewash sprays are operated by the inspectors to mark defective cars. In addition to these sprays, some railroads have installed an electric bell alarm. The inspector, after locating a defect on a car and marking it with the spray, by means of this alarm has the defective car diverted to the bad order track.

Issued Questionnaire

In 1947 a renewed interest in facilities of this kind became evident with the Union Pacific Railroad installation at Pocatello, Idaho. Since the construction of this pit other railroads have constructed or proposed construction of facilities of this type. To determine the extent of the use of these inspection facilities, a questionnaire was submitted to 47 railroads and direct correspondence was carried on with 6 others. Thirty-eight answers to the questionnaire together with information from the direct correspondence furnished the following facts: Prior to 1947 five railroads in the eastern part of the country had built and placed in service 21 pits for inspection facilities. Since 1947 seven railroads have shown interest in this type of facility. The Union Pacific and the Atchison, Topeka & Santa Fe Railway have constructed and placed in service three pits, while three additional western, one eastern and one Canadian railroad are contemplating installations.

The second facility built by the Union Pacific at North Platte, Nebr., sections of which are shown in Figs. 3 and 4, is a five-position inspection station consisting of three

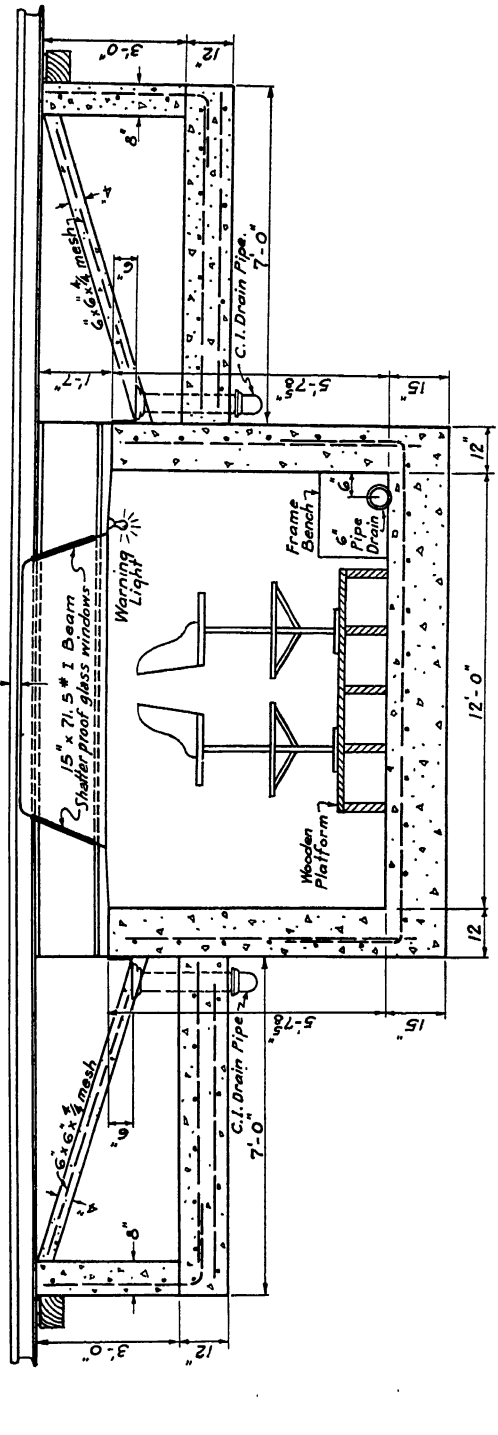

Fig. 6.—Cross Section of Santa Fe Pit (As originally constructed).

tower, there are three sliding windows through which side and roof inspections are made. Flood lights mounted on the towers furnish the necessary illumination. When an inspector observes a defect, by means of a speaker system, he informs a man stationed at track level who decides the disposition of the car. This installation is located 300 ft. in advance of the crest of the hump, which affords ample time to change the switching list if the car is to be switched to the bad order track. A dragging equipment detector is located 100 ft. in advance of the pit.

Facilities contemplated by the Southern Pacific Company and the Chicago, Burlington & Quincy Railroad will follow the general pattern of the Union Pacific installations. Different ground conditions cause variations in the passageway and means of entering the pits.

At Argentine, Kans., the Santa Fe installation consists of a reinforced concrete passageway, sections of which are shown in Figs. 5 and 6, beneath the hump approach track. Enclosed stairways provide access to the passageway. The portion of the passageway between the rails which is used for the inspection station is covered by a steel hood with glass windows. A twin chair installation was originally provided in this pit which accounts for the length. At this time only one inspector is stationed in the pit and the steel hood has been revised accordingly. Flood lights for illuminating the underside of the cars are mounted in depressed areas at each end of the pit.

The pit is located 265 ft. in advance of the crest of the hump and six dragging equipment detectors are located in advance of the pit. Whitewash jets installed beyond the pit are used to mark the rear truck of defective cars and the inspector, by means of a communication system, arranges to have the defective cars diverted. Side inspection pits are contemplated for this facility and will be built at a later date.

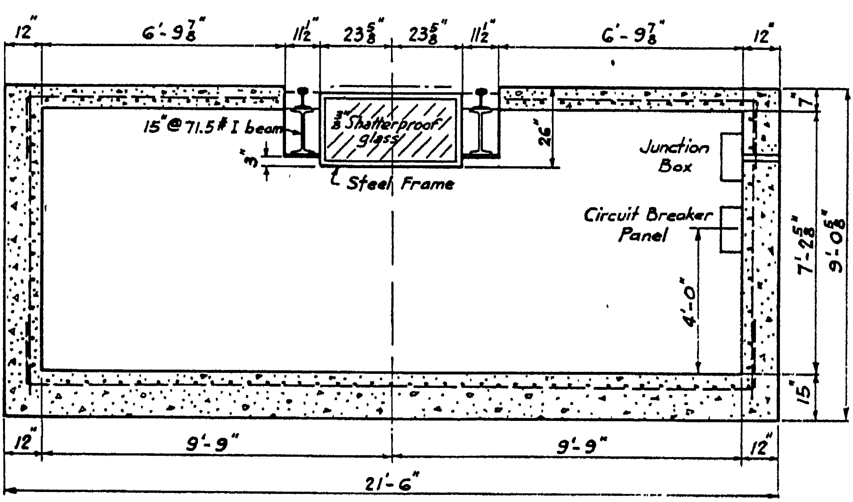

Fig. 5.—Transverse Section of Santa Fe Pit.

Report of Committee 9—Highways

WM. J. HEDLEY, *Chairman,*
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H. D. BLAKE
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F. A. STONE
C. V. TALLEY
R. R. THURSTON
V. R. WALLING
R. E. WARDEN
CHARLES WEISS
J. W. WHEELER

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

THE COMMITTEE ON HIGHWAYS,
WM. J. HEDLEY, *Chairman.*

Warren Henry

Warren Henry was born in Ludlow, Mass. on December 9, 1886, and met his death in a highway accident on August 25, 1949, near Chatham, Ont. His daughter, Alice, 19, was killed and his wife, Helen, severely injured in the accident, in which the Henry car collided with a bus.

Mr. Henry attended Rhode Island State College. For several years, 1910 to 1918, he was engaged in engineering work with industries in the East, including the Lehigh & New England Railway Company; as assistant city engineer of Cairo, Ill.; and in consulting engineering practice.

AREA Bulletin 483, November 1949.

General Observations

To insure no flooding of the pit or interference with the flood lights in the depressed areas, a good drainage system must be provided.

Ample flood lighting systems are needed, and in the case of the side inspection pits, additional lights mounted ln the pit must be used for proper illumination on the outside portion of the underneath section of the cars.

Sufficient distance must be allowed between the inspection pit and the crest of the hump to give ample time for any change in the routing of the defective cars as they are observed and reported.

With a proper communication system this distance can be reduced to a minimum.

Dragging equipment detectors in advance of the pit are desirable.

The facilities should be so arranged that the inspectors do not encroach on live tracks when entering or leaving the pit.

Adjustable height swivel chairs should be provided in the pits.

The window in the hoods of the undercar and side pits should be shatter-proof glass.

REFERENCE LIST OF SPECIFICATIONS

Reference Number	Type of Crossing	Manual Page
1	Bituminous crossings	9–5
2	Wood plank crossings	9–7
3	Prefabricated treated timber crossings	9–9
4	Precast concrete slab crossings	9–13
5	Monolithic concrete crossings	9–17

Report on Assignment 3

Merits of Various Types of Highway–Railway Grade Crossing Protection,

Collaborating with Signal Section, AAR, and Highway Research Board

G. P. Palmer (chairman, subcommittee), H. D. Blake, P. W. Elmore, A. S. Haigh, W. J. Hedley, T. J. Jaynes, R. E. Nottingham, Walker Paul, W. C. Pinschmidt, S. H. Pratt, C. H. Reisinger, P. T. Simons, R. E. Warden, Charles Weiss, J. W. Wheeler.

Your committee submits the following report of progress on the merits of various types of grade crossing protection as information.

The committee this year desires to report on a study and analysis of various types of grade crossing protection on the Wabash Railroad covering a period of 20 years ending with the calendar year of 1948. That study was based upon a complete record of the changes made in crossing protection and a corresponding record of the accidents which occurred during the 20-year period. The comparative effectiveness of the several types of grade crossing protection was determined by comparing the accident records before and after the change in protection.

The complete study and report is published in the Proceedings of the American Railway Engineering Association, Vol. 50, 1949, pages 849 and 864.

The final conclusions were stated in the form of "Accident Quotients," which show the average number of accidents per crossing per year at comparable crossings protected by the several types of protection.

Table 1 is a summary of these accident quotients:

TABLE 1.—ACCIDENT QUOTIENTS FOR SEVERAL TYPES OF PROTECTION

Type of Protection	*Accident Quotient*
Automatic gates—multiple track	0.0925
Manual gates—24 hours	0.1513
Flashing lights—single track	0.1773
Wigwag	0.2936
Flashing lights—multiple track	0.3044
Manual gates—part time	0.3520
Watchmen	0.3581
Automatic bells	0.3941
Reflector signs—AREA Standard	0.4450
Painted crossbuck signs	0.5038
Reflector signs—Michigan standard	0.8156

In 1918 he entered the service of the Public Utilities Commission of the State of Illinois, now the Illinois Commerce Commission, as an assistant engineer. He was, successively, mechanical engineer, assistant chief engineer and chief engineer. He held the latter position from 1946 until the time of his death.

Mr. Henry was a graduate of the Lincoln College of Law in Springfield, Ill., and had been a professor in that institution since 1925. He was a member of the Illinois State Bar Association and the American Bar Association.

Mr. Henry was the author of the Henry formula, which has been widely used in determining the relative hazards existing at railway-highway grade crossings.

He was a member of the Illinois Society of Professional Engineers and the National Society of Professional Engineers. He became a member of the American Railway Engineering Association in 1937 and was a member of Committee 9—Highways, from 1939 until the time of his death. He brought to the committee a wealth of experience and a genuine interest in its work. He will be long remembered by his associates.

Report on Assignment 1

Revision of Manual

H. G. Morgan (chairman, subcommittee), Bernard Blum, D. A. Bryan, H. G. Dimond, A. S. Haigh, C. I. Hartsell, W. J. Hedley, G. P. Palmer, W. C. Pinschmidt, C. H. Reisinger.

Your committee recommends the following revision of the Manual:

On page 9-53, in the notes referring to Fig. 1.—Painted Highway Crossing Sign, delete the second line, which contains the words "and border," and delete from lines 10 to 13, incl., the sentence "Sign shall be white with black letters, unless reflector lenses are used, when letters shall be white on black background."

Report on Assignment 2

Description and Recommended Use of Various Types of Highway-Railway Grade Crossings

C. I. Hartsell (chairman, subcommittee), F. N. Beighley, O. C. Benson, H. D. Blake, H. G. Dimond, W. R. Dunn, J. S. Findley, L. W. Green, W. J. Hedley, G. A. Heft, J. T. Hoelzer, J. R. C. Macredie, R. E. Nottingham, A. C. Palmer, R. J. Pierce, S. H. Pratt, H. E. Snyder, C. V. Talley, R. R. Thurston, V. R. Walling, R. E. Warden.

The following tabulation is recommended for publication in the Manual:

RECOMMENDED USE OF VARIOUS TYPES OF HIGHWAY-RAILWAY GRADE CROSSINGS

Character of Highway or Street	*Type of Crossing Recommended (See reference list below)*	
	In High Speed Tracks	*In Low Speed Tracks*
Improved—heavy traffic	3 or 4	1, 3, 4 or 5
Improved—medium traffic	1, 3 or 4	1, 3, 4 or 5
Improved—light traffic	2, 3 or 4	2, 3, 4 or 5
Unimproved—light traffic	1 or 2	1 or 2

Crossing Situation	*Sign Recommended*	*AREA Manual Reference Pages*
At crossings where watchman service is maintained less than 24 hours daily.	"WATCHMAN OFF DUTY" sign, reflector type, on post at side of roadway, to be displayed only when watchman is off duty. Reflecting medium may be reflector buttons, reflecting material, or reflecting paint.	9–77, 9–79, and 9–80.
At crossings where manual gates are used, but are not operated for the full period of 24 hours daily.	"GATES NOT WORKING" sign, reflector type, on post at side of roadway, to be displayed only when gates are not attended. Reflecting medium may be reflector buttons, reflecting material, or reflecting paint.	9–78, 9–79, and 9–80.

Note: State or provincial laws will govern where there are differences in requirements from any of the foregoing recommendations.

RECOMMENDED USE OF HIGHWAY-RAILWAY GRADE CROSSING SIGNALS

Crossing Situation	*Signal Recommended*	*AREA Manual Reference Pages*
At crossings where an indication of the approach of a train or the presence of a train or cars on the crossing is desired.		
At single track crossings.	Flashing light signal, located as shown on pages 9–95 or 9–96, or	9–93, 9–94, 9–97 and 9–101.
	Flashing light signal, located as shown on pages 9–95 or 9–96, or	9–93, 9–94 and 9–98.
	Wig-wag signal, located as shown on pages 9–95 or 9–96, or	9–93, 9–94, 9–99 and 9–102.
	Wig-Wag signal, located as shown on pages 9–95 or 9–96.	9–93, 9–94 and 9–100.
At multiple track crossings.	Same as for single track crossings, or	9–93, 9–94 and 9–97 to 9–102, incl.
	Automatic crossing gate and signal, located as shown on pages 9–113, 9–114 or 9–115.	9–111, 9–112, 9–116 and 9–117.
Where street or roadway is very wide or where side of the road installations are likely to be obscured.	Cantilever flashing light signal.	9–103 and 9–104.

Note: State or provincial laws will govern where there are differences in requirements from any of the foregoing recommendations.

RECOMMENDED USE OF FLOODLIGHTING

Crossing Situation	*Lighting Recommended*	*Reference*
At crossings, preferably those not otherwise protected by manual or automatic devices, where moving trains or standing cars block highway traffic, or where gradients of approaches are such that headlights of oncoming vehicles shine over or under the railroad cars, or where other conditions result in low or faulty visibility.	A type distinctive in volume, distribution, or color from ordinary street or other lighting, with lights located 20 to 30 ft. above the roadway, on poles 8 ft. or more from the shoulder of the roadway, on the left hand side approaching the track, and 25 to 50 ft. from the nearest track.	9–26.

Note: State or provincial laws will govern where there are differences in requirements from any of the foregoing recommendations.

It will be noted that automatic gates, having the smallest accident quotient, proved to be the most effective form of protection, followed by other types which give warning of the approach of a train, and that those types of protection, such as painted or reflectorized signs, which merely indicate the location of the railroad, are relatively less effective. It is interesting to note the relative ineffectiveness of watchmen and automatic bells in comparison with automatic gates and flashing light signals, which are currently recommended by the AREA.

The Wabash Railroad report is recommended for your careful consideration and acceptance as information. Similar reports on other groups of crossings would be most welcome where the necessary data are available for analysis over a period of years.

Report on Assignment 4

Description and Recommended Use of Various Highway Crossing Signs and Various Types of Highway Grade Crossing Protection

W. C. Pinschmidt (chairman, subcommittee), H. D. Blake, C. O. Bryant, H. G. Dimond, P. W. Elmore, J. S. Findley, C. I. Hartsell, W. J. Hedley, T. J. Jaynes, R. E. Nottingham, A. C. Palmer, R. J. Pierce, P. T. Simons, C. V. Talley, Charles Weiss.

Your committee has studied all of the subject matter covered by the assignment and submits the following tabulation of data with the recommendation that it be approved for publication in the Manual:

RECOMMENDED USE OF HIGHWAY-RAILWAY GRADE CROSSING SIGNS

Crossing Situation	*Sign Recommended*	*AREA Manual Reference Pages*
At crossings where an indication of the location of a railroad is considered to be sufficient.	Painted wood sign with 6-ft. blades at 50-deg. angle on post at side of roadway.	9–53.
Same, but where improved night indication is desired.	Reflector type sign with 6-ft. blades of painted wood or painted or enameled metal at 50-deg. angle on post at side of roadway. Reflecting medium may be reflector buttons, reflecting material or reflecting paint.	9–53 to 9–56, incl.
At crossings where an indication of the location of a railroad is considered to be sufficient, but where space is not available for 6-ft., 50-deg. sign.	Metal sign with 4-ft. painted or enameled blades at 90-deg. angle, on post at side of roadway. Sign may be of wood, painted, similar in construction to that on page 9–53.	9–57 and 9–58.
Same, but where improved night indication is desired.	Reflector type sign with 4-ft. blades of painted wood or painted or enameled metal, at 90-deg. angle, on post at side of roadway. Reflecting medium may be reflector buttons, reflecting material or reflecting paint.	9–57 to 9–62, incl.
At crossings where an indication of the location of a railroad is considered to be sufficient, but when space is not available for sign on post at side of roadway.	Suspended overhead sign, with 4-ft. enameled steel blades at 90-deg. angle, over highway, on wires between posts.	9–67 to 9–70, incl.
Same, but where improved night indication is desired.	Suspended overhead reflector type sign, with 4-ft. steel blades at 90-deg. angle, over highway, on wires between posts. Reflecting medium may be reflector buttons, reflecting material or reflecting paint.	9–67 to 9–72, incl.

lights, crossing gates or other devices deemed suitable by both the state highway department and the railway company concerned and approved by the Public Roads Administration.

3. At all other crossings protection shall be provided by reflectorized advance warning signs and reflectorized railway crossing signs of the crossbuck type except that
   (a) at crossings of important trunk highway with main and branch line railways which are not high speed lines, one of the methods enumerated under 2 may be required.
   (b) at crossings not used for night railway operations and at crossings where a satisfactory agreement is made or is in effect that train movements will be flagged across, protection may be provided by nonreflectorized advance warning signs and nonreflectorized railway crossing signs of the crossbuck type.

   (Note: It has been estimated that there are about 1500 railway-highway grade crossings on the federal-aid system that carry less than 300 vehicles per day, and that there are about 11,000 railway-highway grade crossings on sections of the present federal-aid secondary system that carry less than 500 vehicles per day.)
4. Flood lighting of crossings is recommended where especially hazardous conditions exist and where it is practical to install same.
5. At all crossings under any of the above classifications the protection secured shall not operate to prevent the future elimination of any such crossing.

Replies from 46 states and the District of Columbia commented as follows:

20 approved without comment
15 approved with minor comments
5 suggested partial revision
7 suggested complete revision

It is interesting to note specifically some of the comments that have been made by those suggesting complete revision, which are as follows:

Arizona.—The use of gates as a general highway requirement is not necessary when proper advance warning and flashing signals are installed.

California.—The use of gate arms should not be made mandatory. Evidence applied by a two year record of accidents at grade crossings gives no support for the suggestions that there is an urgent need for further protective devices This study indicates that the most general hazard is that of motorists running into the side of freight trains at night. Simply adding a short arm gate to existing signals could not be expected to aid substantially in preventing this type of accident.

Illinois.—Too much consideration is given to train speeds. Primary factors should be volumes of train and highway traffic and resulting exposure factor. (A completely revised suggested policy was submitted, in which type of protection was determined by using a modification of the Warren Henry formula.)

Kansas.—Method of protection could be set up for four or five different types under which could be listed the general traffic conditions for which that type would usually be considered the minimum acceptable protection. Requirements should not be too rigid and special conditions should call for special consideration and treatment. Perhaps light signals which would more successfully compete with commercial advertising could be obtained if the AASHO and the

Report on Assignment 5

Method of Classifying Highway–Railway Crossings with Respect to Public Safety

W. H. Huffman (chairman, subcommittee), O. C. Benson, H. D. Blake, C. O. Bryant, J. A. Droege, Jr., J. S. Findley, W. J. Hedley, J. W. Jones, R. B. Kittredge, A. E. Korsell, J. R. C. Macredie, R. W. Mauer, F. T. Miller, A. C. Palmer, Walker Paul, C. H. Reisinger, D. A. Steel, F. A. Stone, C. V. Talley, J. W. Wheeler.

This is a progress report presented as information.

The last previous report made by this committee was an analysis of formulas developed and used by various states throughout the nation. The ratings of crossings by means of the various formulas give inconsistent results and, at present your committee has no way of determining which formula is most nearly correct. Daily volume of vehicular and train traffic, sight distance, train speed and number of tracks appear to be the factors which are used to the greatest extent in all the formulas. Of 29 states not using formulas, 14 depended upon independent engineering judgment.

On May 5, 1947, a rough draft of a suggested policy on protective devices at railway-highway grade crossings was submitted to all of its members by the Committee on Planning and Design Policies, American Association of State Highway Officials, which is presented below.

> On federal-aid projects involving new construction at railway-highway crossings where grades are not separated, the following forms of protective devices shall be provided:
>
> 1. (a) At all crossings of primary highways with an average daily vehicular traffic of 300 or more and with 2 or more main line railway tracks on which there are 6 or more trains daily operating at speeds of 60 mph. or more, protection shall be provided by approved flashing light signals and short arm gates supplemented by reflectorized advance warning signs.
>
>   (Note: It has been estimated that there are about 4900 railway-highway grade crossings on the rural sections of the federal-aid systems that carry more than 300 vehicles per day.)
>
>   (b) At all crossings of secondary highways carrying predominantly local highway traffic at average speeds of about 35 mph. or less in volumes of more than 500 vehicles per day and with 2 or more main line railway tracks on which there are 6 or more trains daily operating at speeds of 60 mph. or more, protection shall be provided by approved flashing light signals and short arm gates supplemented by reflectorized advance warning signs.
>
>   (Note: It has been estimated that there are about 2000 railway-highway grade crossings on the present federal-aid secondary system that carry more than 50 vehicles per day.)
>
> 2. At all crossings with an average daily vehicular highway traffic of 300 vehicles or more and with one or more main line tracks with or without passing tracks on which
>
>   (a) there are less than 6 trains daily operating at 60 mph. or more,
>
>   (b) all crossings with restricted visions,
>
>   (c) all crossings with below standard approach grades,
>
>   protection shall be provided by reflectorized advance warning signs with approved flashing light signals, short arm gates in combination with flashing

rather than the so-called net benefit method. The latter method has not worked out satisfactorily in practice due to wide differences of opinion as to what factors should be considered as benefits and as to how the amount of such benefits should be computed.

The committee specifically recommends the following schedule of percentages to cover the railroad company's participation in the various types of grade crossing work. Supporting data follow the schedule.

1. *Grade Crossing Eliminations.*—This group shall include all projects involving the separation of grades at existing railway-highway grade crossings whether accomplished by carrying the highway over or under the railway, or by the relocation of either the railway or highway. In such cases the cost to the railroad company shall be as follows:

(a) Where the grade crossing designated in the proceedings for elimination is closed to all traffic, the railroad company's share of the cost will be 10 percent.

(b) Where the grade crossing designated for elimination is not completely closed, but is left in service for local traffic, the railroad company should pay nothing.

2. *Reconstructions.*—This group shall include all existing grade separation structures which are to be rebuilt, whether by replacement, widening, strengthening, or relocation. In all such cases where the work is initiated by the public authority, the railroad company should pay nothing.

3. *Alteration of Grade Crossings.*—This group shall include all cases where an existing grade crossing is rebuilt, widened, or relocated. If the work is the result of a highway improvement, the railroad company should pay nothing. If the work is for the sole benefit of the railroad company, it should pay the entire cost.

4. *New Railway-Highway Crossings.*—Where a new street or highway is extended across an existing railroad, the construction of a grade separation structure or the installation of a grade crossing and protective devices shall be done at no cost to the railroad company.

Where a railroad company extends its track across an existing street or highway, by means of a grade separation structure or a crossing at grade, the cost of the structure or the grade crossing and protective devices shall be borne wholly by the railroad company.

5. *Grade Crossing Protection.*—This group shall include all installations of automatic protection devices, whether wholly new, or the modernization or improvement of an existing device. In such cases the public authority should bear the full cost of installation.

6. *Maintenance.*—In the case of a structure carrying the railroad over a highway, the railroad should maintain the superstructure and its supports.

In the case of a structure carrying the highway over the railroad, the public authority involved should maintain the entire project, with the exception of blast plates, if used.

In the case of grade crossing automatic protection devices, the railroad should maintain them at its sole expense.

AREA jointly employed an outdoor advertising expert to redesign flashing light signals.

Ohio.—Recommends a higher number of possible traffic conflicts as the minimum for the combination of flashing light signals and short arm gates, also elimination of the definite policy of short arm gates where switching is predominant.

Oregon.—This attempt to set up specifications or warrants for national application runs into the same stumbling block we have run into before, namely, that all things are relative and it is difficult to set up warrants which would be applicable to all states alike. It is probable that in states such as Pennsylvania, if a priority listing with respect to all the crossings in the state comparable to the list we have in Oregon were made up and the upper half cut off, the lower half would list crossings with a much greater inherent hazard than any to be found in Oregon. Under such circumstances a set of warrants used as a basis of grade crossing protection in Pennsylvania would not even "touch" our crossings in Oregon, with the result that we would not even consider installation of protective devices in this state.

Texas.—The proposed policy may be at fault in that it sets up the minimum warrants for flashing light signals at much too low a figure for certain conditions, and is not comprehensive enough to provide proper protection for all conditions. For example, the policy would require flashing light signals at a crossing carrying 6 trains and 300 vehicles, but would not provide flashing lights at a crossing carrying 5 trains and 5000 vehicles. It is apparent that the chances of simultaneous arrival at a given crossing increases in direct proportion to the product of the number of trains multiplied by the number of vehicles. Also, it is generally conceded that the actual hazard varies with the vehicular and train speeds. (A suggested revised policy was submitted using the above factors as a basis.)

It is the committee's opinion that a policy of protective devices at railway-highway grade crossings cannot be set up without first developing a satisfactory and complete set of principles to grade the crossings as to their relative hazard to public safety. It is recommended that the railway companies perhaps represented by the AREA be full parties to any policy to be adopted by the AASHO or other highway group. Also, that any policy should have sufficient flexibility so that the provisions would not have to be adhered to in each specific instance. Your committee will continue to progress its study of this subject.

Report on Assignment 6

Principles for Determining Allocation of Cost of Public Improvement Projects Affecting Highway–Railway Crossings

J. A. Droege, Jr. (chairman, subcommittee), H. D. Blake, L. W. Green, W. J. Hedley, G. A. Heft, W. H. Huffman, T. J. Jaynes, J. W. Jones, J. R. C. Macredie, R. W. Mauer, F. T. Miller, Walker Paul, W. C. Pinschmidt, P. T. Simons, H. E. Snyder, F. A. Stone, V. R. Walling, J. W. Wheeler.

This report is submitted as information.

The committee recommends that a system of fixed percentages be used for determining the railroad company's share of the cost of railway-highway crossing work,

2. Reconstructions

The great majority of reconstructions of grade separation structures are done as a result of some improvement to the highway. In such cases the railroad not only receives no benefit, but is usually saddled with some additional expense in the form of increased taxation or maintenance. In these cases it is felt that the public authority initiating the improvement should bear the full cost.

In unusual cases where the railroad desires to reconstruct, for some such reason as the relocation of its line, the improvement of its alinement, either horizontal or vertical, or to accommodate additional trackage, then the railroad should bear the full cost.

3. Alteration of Grade Crossings

Once a grade crossing has been established and the cost allocated in accordance with Section 4, then any modification of it thereafter should be paid for wholly by the party or parties desiring same. It is quite common for a railroad to have to widen a crossing, rebuild it, rehabilitate its track, change right-of-way fence and pole lines, and furnish additional protection, paying anywhere from 50 to 100 percent of the cost, all on account of a highway improvement. This is patently unfair, and the public authority should pay the entire cost in such cases. Where the reverse is the case and the work is necessitated by some change in the railroad's facilities, it should, of course, bear all of the expense.

4. New Railway–Highway Crossings

In the case of new crossings it seems quite evident that it is equitable to leave the first occupant free of cost whether a subway, overhead or grade crossing is involved. The agency desiring to extend its facilities across the existing facilities of the other should bear the full cost.

Both New York and New Jersey have passed laws which recognize this principle. New York State, in the construction of its "Thruways," pays the full cost of any railway-highway grade separation structure involved, and New Jersey does likewise with respect to its "Freeways."

Furthermore, it is the present policy of both states to pay the full cost of grade separation structures on state highways, in cases of new crossings where no grade crossing in the vicinity was eliminated as a result of the new structure.

5. Grade Crossing Protection

While it is felt that the highway user receives practically all the benefit from the standpoint of safety as the result of the installation of automatic protective devices, it is also true that the railroad derives some benefit economically due to reduced accident costs. It is believed that an equitable allocation of costs would require the public authority to install the protection at its sole cost, and make the railroad responsible for the maintenance and operation thereof. The actual maintenance would have to be done by the railroad in any case, and there is good reason to avoid the bookkeeping and accounting which would be required if the public authority shared in the cost of maintenance and operation. Therefore, if the railroad is to maintain and operate the protection at its sole cost, it is only fair that the installations' costs be borne entirely by the public authority.

Reasons for Recommendations in the Foregoing Schedule

1. Grade Crossing Eliminations

During the past 10 years there has been substantial revision downward in the cost to the railroad of elimination work. The following examples are cited:

1939:

New York —Old law 50 percent for railroad reduced to 15 percent maximum on a benefit basis.

Ohio —Old law 50 percent to 65 percent for railroad reduced to a flat 15 percent.

Indiana —Existing law fixing railroad cost for state highway crossings at 20 percent extended to include crossings in cities and towns.

Michigan —Old law 50 percent for railroad reduced to 15 percent maximum on a benefit basis.

1944:

Federal Aid Highway Act of 1944 established the railroad cost at 10 percent maximum on a benefit basis. The Rules and Regulations (G.A.M. No. 325) administering this act have since revised this to a flat 10 percent, with no railroad participation if the crossing is not closed.

1947:

New Jersey —Old law 50 percent for railroad reduced to 15 percent flat, with several approach items excluded from the joint cost (paving, sidewalks, curbs, guard rails and landscaping).

West Virginia—Old law 50 percent to railroad reduced to a flat 10 percent.

Louisiana —An agreement was entered into on October 22, 1947 between nine railroads and the City of New Orleans whereby the railroads share in the cost of a comprehensive grade crossing elimination program involving 27 crossings was set at 15 percent. The cost of such work in the state has generally been 50 percent.

1949:

New Mexico —Old law 50 percent to railroad reduced to a maximum of 10 percent.

When the exclusion of the approach items in New Jersey is considered, the result is that the railroad cost is closer to 10 percent than to 15 percent. The general trend seems to start at 50 percent and work down through 15 percent or 20 percent participation to 10 percent which is the effective rate set in the last four examples cited above.

It is thought, therefore, that 10 percent is a fair and reasonable amount for the railroad to contribute toward the cost of eliminating a crossing. If, however, the crossing is left open to some highway traffic, then the railroad is still confronted with the cost of maintaining and operating it, as well as the possibility of expense due to accidents, and in such cases, it should pay nothing toward the cost of the project.

Report of Committee 3—Ties

B. D. Howe, *Chairman,*
S. H. Barlow
R. S. Belcher
H. J. Bogardus
W. C. Bolin
C. S. Burt
W. J. Burton
R. F. Bush
R. E. Butler
G. B. Campbell
E. L. Collette
W. P. Conklin
B. S. Converse
R. L. Cook
R. W. Cook
T. Crawford
B. E. Crumpler
W. T. Donoho
L. P. Drew
H. R. Duncan
H. C. Fox
T. H. Friedlin
W. E. Fuhr
L. E. Gingerich
R. H. Jordan
L. W. Kistler
C. R. Lapeza
J. R. Latimer
C. M. Long
Roy Lumpkin
F. L. McLean
R. B. Midkiff
W. O. Nelson
P. D. Brentlinger, *Vice-Chairman,*
L. E. Peterson
L. H. Powell
W. C. Reichow
E. F. Salisbury
T. D. Saunders
C. K. Scott
H. W. Seeley, Jr.
F. S. Shinn
Stuart Shumate
J. G. Sutherland
P. V. Thelander
S. Thorvaldson
C. D. Turley
B. J. Worley

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Extent of adherence to specifications.
   Progress report, presented as information .... page 212

3. Substitutes for wood ties.
   Progress report, presented as information .... page 213

4. Tie renewals and costs per mile of maintained track.
   Progress report, presented as information .... page 213

5. Methods of retarding the splitting and the mechanical wear of ties, including stabilization of wood, collaborating with NLMA.
   No report.

6. Bituminous coating of ties for protection from the elements.
   Progress report, presented as information .... page 214

7. Causes leading to the removal of ties.
   No report.

8. Prebored ties: Benefits and factors affecting economy.
   No report.

The Committee on Ties,
B. D. Howe, *Chairman.*

AREA Bulletin 484, December 1949.

6. Maintenance

G.A.M. No. 325 of the P.R.A. leaves the question of maintenance to negotiations between the state and railroad. In many instances the railroad is required to maintain the superstructure and its supports of the span carrying its tracks, or carrying the highway over its tracks. This is believed to be inequitable and the new West Virginia law takes cognizance of this, and requires the railroad to maintain the structure only if it carries its tracks.

Your committee believes that the railroad or the public authority. should maintain the structures carrying their respective facilities. The highway and approach aspects of the elimination should be maintained by the public authority, just as the railroad maintains its track, signals and other facilities in the vicinity of the elimination structure.

The matter of mantenance of grade crossing protective devices has been covered in Section 5.

Table A

GROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I STEAM RAILWAYS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1948

Report on Assignment 2

Extent of Adherence to Specifications

P. D. Brentlinger (chairman, subcommittee), R. F. Bush, R. E. Butler, G. B. Campbell, E. L. Collette, T. Crawford, B. E. Crumpler, T. H. Friedlin, L. W. Kistler, C. R. Lapeza, J. R. Latimer, F. L. McLean, W. C. Reichow, E. F. Salisbury, C. K. Scott, F. S. Shinn, P. V. Thelander, S. Thorvaldson, B. J. Worley.

This is a progress report, presented as information.

One field trip was completed by Committee 3 up to the time this report was prepared.

Three wood preserving plants in two western cities, that contained cross ties for five railroads, were inspected by the committee in the spring of 1949. A total of 1,175,000 pine, oak and gum cross ties were stored for seasoning at the three plants.

The presence of weeds and poor drainage and poor stacking were observed at the treating plants. Weeds are not only unsanitary but create a fire hazard after they become dry. Poor drainage not only retards proper air-seasoning but provides moisture for wood destroying organisms. The poor stacking, mentioned above, was not prevalent at all of the plants. The crowding of too many ties on one course was largely responsible for this comment. In addition to crowded rows many tie piles were too close to the ground to insure an adequate circulation of air currents to season the ties properly.

The mechanical handling of ties from cars to stacks has generally improved the stacking of ties. Only when careless crane or lift truck crews jumbled layers of ties was poor stacking evident.

Three railroads were not branding ties in accordance with the AREA specifications for branding. One railroad accepts cross ties on producer's count and grade and later inspects the ties as they are stacked. While an inspector can detect many improperly sized and decayed ties, he cannot inspect each tie on four sides and two ends. From the number of incorrectly sized ties in the seasoning stacks it appears to be false economy to imagine this method of inspection saves the railroad money. One railroad's ties were obviously accepted with little regard for the AREA specification for size and quality.

Adherence to the AREA specifications for cross ties is not only important to the railroads to insure the acceptance of a properly sized and sound tie but is also important to the tie producers. Tie producers are sincere in their effort to provide the railroads with the kind of cross tie required for a well maintained track, but, those railroads which continue to procure ties on a price based on lax and improper inspection make it difficult for the railroads intent on obtaining the best tie possible to compete in the production field. The fact that some railroads accept ties that deviate from the specifications to which they have subscribed has given rise to a movement on the part of the producers for the amendment of the specifications to fit such acceptance practice.

Only by proper supervision and explicit instructions to inspectors can the railroads obtain ties that conform with AREA specifications. Maintenance engineers should be vitally interested in the kind of ties made available to them. Only by the use of full-sized and sound ties can a track be maintained to assure long service life from cross ties.

Report on Assignment 3

Substitutes for Wood Ties

L. P. Drew (chairman, subcommittee), W. C. Bolin, W. E. Fuhr, R. H. Jordan, J. R. Latimer, Stuart Shumate, B. J. Worley.

This is a progress report, submitted as information.

The statement showing a record of test installations of substitute ties as published in the Proceedings, Vol. 41, 1940, page 648, has been brought up to date, but since nothing of value was developed it was not considered worthy of republication.

Practically all of the original test installations of substitute ties have now been removed and so far as your committee has been able to determine no new installations have been made. The results of the tests were generally unsatisfactory and none of the substitute ties was adopted by any road.

A check was made of the records of the U. S. Patent Office and it was found that since 1940, 18 patents that appear practical were issued for cross ties of other materials than wood. Four of the ties were of concrete, one of laminated wood and concrete, and the others of metal. Through correspondence with patentees it develops that no ties under any of the patents have been installed for test.

Some interest is being shown in ties of plastic materials, but none has been manufactured as yet. Your committee will keep in touch with developments in the pastic field.

In England and France a considerable number of concrete ties with prestressed reinforcing have been manufactured, but your committee has been unable to develop costs, service life or other factual information. The investigation will be continued.

In the July 1949 issue of the Cross Tie Bulletin, a very interesting article by Professor Nelson C. Brown of New York State College of Forestry outlined his conclusions following 40 years' of study of the cross tie problem, both in Europe and the United States.

In Switzerland, France and Germany the tests of metal ties resulted in complete failure due to excessive corrosion, and they have now been replaced by wood cross ties. In this country steel ties placed in yard tracks at steel mills have largely been replaced by wood ties.

Since none of the 2500 patents issued for substitute forms of cross ties during the past years has been adopted by the railroads, it appears that the materials for substitute ties should be extended to include noncorrosive metals, plastics or other more durable substances.

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

B. D. Howe (chairman, subcommittee), H. J. Bogardus, W. C. Bolin, R. E. Butler, R. L. Cook, W. T. Donoho, T. H. Friedlin, C. R. Lapeza, W. O. Nelson, L. H. Powell, T. D. Saunders, J. G. Sutherland.

This is a progress report, presented as information.

Information reported annually to the Interstate Commerce Commission by Class I steam railroads in the United States, and to this Association by large railroads in Canada, regarding the number and cost of cross ties laid in replacement, is supplied for the year 1948 in Tables A and B.

Report of Committee 6—Buildings

A. G. Dorland, *Chairman,*	A. H. Exon	J. B. Schaub, *Vice-Chairman,*
F. H. Alcott	M. C. Fleming	I. A. Moore
C. M. Angel	R. L. Fletcher	G. A. Morison
W. F. Armstrong	J. P. Gallagher	B. M. Murdoch
G. A. Belden	C. S. Graves	W. C. Oest
E. D. Billmeyer	W. G. Harding	J. S. Parsons
C. E. Booth	J. W. Hayes	C. R. Pritchard
H. M. Booth	R. V. Hazer	J. J. Schnebelen
E. Christiansen	J. F. Hendrickson	J. T. Schoener
H. M. Church	V. V. Holmberg	E. W. Scripture, Jr.
C. E. Close	K. E. Hornung	E. R. Shultz
G. V. Coffey	C. D. Horton	J. E. South
D. W. Converse	B. J. Johnson, Jr.	O. W. Stephens
C. O. Coverley	L. P. Kimball	S. G. Urban
L. B. Curtiss	Earl Kimmel	W. E. Webb
W. T. Dorrance	S. E. Kvenberg	J. W. Westwood
V. E. Elshoff	L. H. Laffoley	O. G. Wilbur
T. J. Engle	C. E. Lex, Jr.	H. C. Zepp
	H. C. Lorenz	*Committee*

To the American Railway Engineering Association:

Your committee reports on the following subjects:

The Committee on Buildings,
A. G. Dorland, *Chairman*

AREA Bulletin 484, December 1949.

The number of ties applied in 1948 was somewhat less than in 1947, and the average cost per tie was approximately $0.18 more.

In order to make the information available as promptly as possible, these tables were published in Bulletin 481, June–July 1949.

Report on Assignment 6

Bituminous Coating of Ties for Protection from Elements

R. W. Cook (chairman, subcommittee), R. F. Bush, E. L. Collette, R. L. Cook, T. Crawford, H. C. Fox, L. E. Gingerich, C. M. Long. Roy Lumpkin, R. B. Midkiff, W. O. Nelson, H. W. Seeley, Jr., Stuart Shumate, J. G. Sutherland.

This is a progress report presented as information.

Protective coatings on ties to retard and protect checking are being tested by several roads in this country and Canada. Practically all of these tests are in their infancy and no definite conclusion can be drawn at present. One road that is making a test reports as follows:

> Test was inspected in detail August 2, 1949. Special attention was given to *blistering,* condition of compound, effect it would have on the tie surface, etc. A great number of these blisters have broken, compound has resealed itself and in no case have the tie surfaces been exposed. By that is meant there is compound still adhering to the wood, with no break which might permit water to enter into the tie from the top. This blistering however seems to be more pronounced on ties that have not opened or checked, or on ties with the least service (freshly treated). To date, I wouldn't say these blisters are a serious defect. The general condition of the entire test after nearly two years is as follows: the film that developed seems a little thicker although still plastic, and when opened the compound seems the same, i.e., jet black—adhering and still as elastic as the original application.
>
> It was noted that in the cool of the morning the coating compound as a whole seemed firmer, but by noon it was soft and movable by foot pressure although the film would stretch ½ to ¾ in. before breaking open and exposing the material underneath. This in itself indicates it gets hard when cold but returns to its original consistency when warm. Another winter may prove its worth, for if it stands the third winter and still remains plastic, then it is a matter of one helping the other, the creosote helping the coating and the coating helping the creosote by retarding the evaporation of the light fractions in each other.
>
> In general the compound is doing all it was expected to do although there are signs of failure, small signs, but it was noticeable and that is where the coating was too thin (due to spraying and too much care was given to keep the ballast clean at the ends). A little flaking was noticed on a few ties, nothing serious as yet but it will be watched in the future. I can advise now, in spite of the flaking, no water can get underneath the compound, for where the compound was properly applied (thick) it is adhering to the surface satisfactorily.

All checks less than a ½ in. are still bridged; some even can be called splits. The compound is still adhering to the ends where it spanned the checks during the application. To date it is satisfactory and looks good.

coal furnaces are started, there would not be enough heat created to accelerate the smoke columns to rise fast enough if fans were not used.

Telescopic hoods from the working height of the hood could be installed so they could be lowered when the fires are being started. Dampers in roof fan ventilators are essential. During the cold months, dampers should be closed at night so that the heat in the building produced during the day will be preserved during the night.

2. The large type blacksmith shop.

In buildings where steam hammers and heat-treating furnaces are used and where the ventilation condition covers heat and smoke, the proper size ventilators are figured on a different basis. The furnaces are mostly heated by oil or gas and it should be an established rule that the operators for the blacksmith shop should know the quantity of oil or gas which is being used for these furnaces. The correct air changes required in these large blacksmith shops will be based on the oil or gas consumption in terms of Btu.

As a matter of information, the following Btu. heat values are in use.

Natural gas 1000 Btu. per cu. ft.
Manufactured gas 500 Btu. per cu. ft.
Fuel oil, type C, 145,000 Btu. per gal.

If the estimated gallons of oil or cubic feet of gas have been established, the correct amount of air exhaust is based on the following formula:

$(\text{Btu.} \times 55) \div (60 \times 25) = \text{cubic feet of air to be exhausted.}$

The figure 55 stands for the cubic feet of air which will absorb one Btu. per one degree of temperature (F.). The figure 25 stands for the average temperature difference to be obtained. The figure 60 is used to establish a per minute basis of air to be exhausted.

Either a ridge ventilator or fan ventilators may be used.

If the air inlets are adequate and the surrounding buildings are not much higher than the blacksmith shop building, a ridge ventilator of the proper size may be used, but if air inlets are interfered with and higher buildings surround the blacksmith shop, fan ventilators should be used. When motor driven fan ventilators are used, experience shows they should be spaced on an average of 20 ft. apart. Air inlets should be figured on a 2 to 1 basis.

Example:

Blacksmith shop has the following dimensions:

80 ft. wide and 200 ft. long, an average height of 30 ft., total cubical capacity of 480,000 cu. ft.

Located in the building are 20 furnaces each consuming 25 gal. per 8-hour day. This gives 500 gal. total or 62½ gal. per hour. Btu. value per gallon is 145,000. $62\frac{1}{2} \times 145{,}000$ Btu. $= 9{,}062{,}500$ Btu. Allowing a 15-percent loss in the heat value through the building, it will be necessary to take care of 7,703,125 Btu. per hour.

To arrive at the cubic feet that absorb the given Btu. value, the following formula is used:

$(7{,}703{,}125 \times 55) \div (60 \times 25) = 282{,}448$ cfm.

If the building is located and proper air inlets are installed so that a ridge ventilator could be used, then to arrive at the proper size of the ridge ventilator, the calculation is as follows:

Report on Assignment 1

Revision of Manual

J. B. Schaub (chairman, subcommittee), G. A. Belden, H. M. Church, C. E. Close, D. W. Converse, C. O. Coverley, W. T. Dorrance, C. S. Graves, J. W. Hayes, L. H. Laffoley, H. C. Lorenz, O. W. Stephens, O. G. Wilbur.

Your committee submits for adoption and publication in the Manual, the recommendations covering the ventilation of railway shop buildings which were presented as information in 1947—Proceedings, Vol. 48, 1947, pages 319 to 325, incl.

VENTILATION OF RAILWAY SHOP BUILDINGS

Blacksmith Shop

As an average, there are two types of blacksmith shop.

1. The small type where only individual open coal furnaces are operated.

   (a) If no crane interferes, small hoods over these coal furnaces may be installed with a proper stack. These stacks should be capped off with the proper design of ventilator, rather than a common rain cap. The common rain cap so often used does not have any pulling power, since sufficient displacement is not present, and may cause the passing wind to enter this stack and create a down draft.

   Where individual stacks are used the height of the stack with the ventilator should be such that the top of the ventilator is on even line with the peak of the roof of the shop. Fans may be used in these stacks when necessary.

   (b) Exhausts from forges may be collected in properly apportioned ducts and then be discharged through one or more central stacks. This system, of course, presupposes the use of low velocity suction fans.

   (c) Downdraft system may be the same type as described in (b), except that the ducts would be in the floor. This method would be used where overhead construction, such as cranes, would interfere with overhead ducts.

The sides of the hood over the coal furnaces should be built on a 45-deg. angle. The diameter of the hood should be at least 2 ft. larger than the diameter of the coal furnace and should start at about 7 ft. from the floor. To secure satisfactory ventilation, the formula giving the proper size of the stack and ventilator should be based on 10 percent of the area of the hood.

Example:

If the diameter of the coal furnace is 5 ft., the hood should be not less than 7 ft., equal to a cross-sectional area of 38 sq. ft. The cross section of the stack and ventilator should have an area 10 percent of the 38 sq. ft., equal to 3.8 sq. ft. or 30-in. diameter (the nearest standard size).

For the general ventilation of the small blacksmith shop a minimum of 8 air changes an hour should be provided. Round natural-draft ventilators or ridge ventilators can be used. It is important that air inlets be checked and the area of the air inlets should be at least twice the area of the outlet.

In case overhead cranes interfere with the hoods and stacks over the coal furnaces, 20 air changes per hour should be provided. This will necessitate the use of motor driven fan ventilators. The reason for this is that in the morning when the shop opens and the

The large freight and passenger diesel engine averaging 4000 hp. for two units and having a total length of approximately 140 ft. will exhaust from 6000 to 7000 cfm. for every 8 cylinders.

The fumes exhausted contain a maximum of 0.5 percent of CO (carbon monoxide) and an approximate 2 percent of SO_2 (sulfur dioxide). Carbon monoxide is a deadly fume which must be exhausted at once. Sulfur dioxide, although not poisonous, reacts unfavorably on the eyes. The exhaust velocity of the gases runs from 1000 to 3000 lin. ft. per min. depending on the speed of idling. The temperature of the gases runs around 400 deg. F.

By actual test and observation, the most practical way to remove these fumes, especially when the operator speeds the motor, is to install the required number of fan ventilators on the roof of the low section. There should be one fan ventilator for every 20 ft. with a minimum capacity of 10,000 cfm. At least 7 to 8 fan ventilators should be installed for a 2-unit 4000-hp. locomotive having a total length of about 140 ft. This type of installation eliminates obstructions over the top of the diesel, making it more convenient for the men working.

To create a reservoir and quicken the time of exhausting the fumes when an engine is being tested a baffle of about 6 ft. should be installed between the low and high sections of the shop.

Heavy Repair Section

In the high section of the repair shop, ventilation of gases is more simple. From 12 to 15 air changes an hour are necessary depending on the height of the building. All ventilators should be of the motor-driven type. Furthermore, each one should be equipped with a damper which should be motor controlled. A 3-way push button control should be installed for the following purposes:

(a) To operate the ventilators on natural-draft with damper open and fan not running.
(b) To operate the fan.
(c) To close the ventilator.

By this control, operation of the fan units with the dampers being closed will be eliminated.

Air inlets are important and should be placed under the platform section as well as above the working platform at a height of approximately 4 to 5 ft.

Cleaning Room

This section of the shop needs 50 air changes per hour. It is desirable that the cleaning tubs be located in a line against the wall and a baffle should be used to prevent fumes traveling in the other part of the room. Fan ventilators should be used.

Battery Room

The battery room should have 3 air changes an hour. Fan ventilators should be used.

Foundry

Foundry buildings are of two types, namely those making steel castings and those in which castings are of nonferrous metal.

For the steel casting foundry, 20 air changes per hour are needed. The use of a ridge ventilator depends on the air inlets and the location of the building in relation to the surrounding other structures. If conditions are favorable, a ridge ventilator may be used, otherwise fan ventilators. Dampers should be provided in both fan and ridge ventilators.

Air velocity through ventilator at a 30-ft. height and a 25-deg. difference of temperature shows 400 lin. ft. per min. The square foot exhaust area for the 282,448 cu. ft. of air to be exhausted will be 282,448 ÷ 400 = 706 sq. ft.

The ridge ventilator should be installed over the whole length of the building, namely 200 ft. The size or width of the 200-ft. ridge ventilator will be 706 ÷ 200 = 3.5 ft. or 42 in., and since the nearest standard unit is 48 in., the recommendation should be that a 48-in. ridge ventilator 200 ft. long be installed.

If air inlets are deficient and higher buildings surrounded the blacksmith shop, the recommendation will be the use of motor-driven fan ventilators. Since the building is 200 ft. long and ventilators spaced on an average of 20 ft., the recommendation should be 10 fan ventilators, each to exhaust a minimum 28,245 cfm.

One solution to this problem, according to the established exhaust capacity of the various fan units, would be a 54-in. roof ventilator with a 48-in. fan running approximately 870 rpm. (3 hp.), which will give close to 30,000 cfm. dampers in ridge and fan ventilators are required.

Boiler House

Twenty air changes per hour with proper air inlets are ordinarily needed; however, this could be varied according to the local conditions. Ridge or round natural-draft ventilators can be used. Dampers are required.

Carpenter Shop

Two to three air changes per hour are needed. Round natural-draft ventilators should be used with dampers. The advantage of using round ventilators in this case is that there may be a certain section of the building where more ventilation may be required than originally recommended, and it is a simple matter to install fan units in existing roof ventilators, which will increase the air changes at least 3 to 4 times that furnished by natural-draft ventilators.

Change House or Washer, Locker and Toilet Building

Where mechanical ventilation is used in such buildings, 10 to 15 air changes per hour should be considered. Proper air inlets are essential.

Diesel Engine Repair Shop

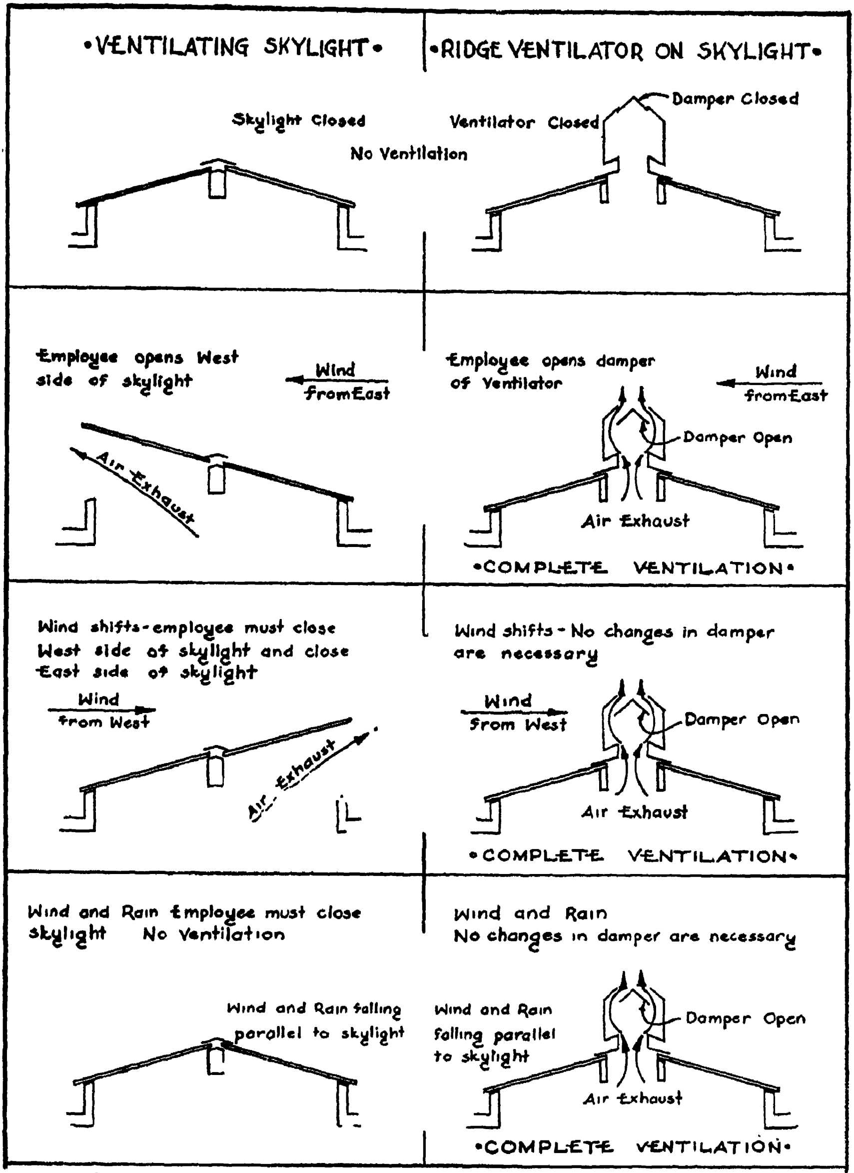
There are two types used, roadway and terminal; of these the terminal-type repair shop will be discussed since it covers practically all the activities required in maintaining diesel locomotives.

Since different types of diesel engines have the gas exhaust located in different places on top of the engines, it is not always practicable to build hoods similar to those used in steam engine roundhouses.

Ventilation in this shop will cover two separate requirements; first, that section of the shop where tuning and light repairs are done, and, second, where heavy repairs are made. In designing new shops, the tuning-up section generally has a low ceiling, whereas the heavy repair section has a rather high ceiling since there is need of a heavy crane.

Tuning and Light Repair Section

In this section, usually no cranes are used. The height betwen the top of the diesel engine and the ceiling varies. The tuning up of each engine takes about 15 to 20 min. If new valves or piston rings are installed, the engine has to run at least one to two hours continuously.



Ventilating Skylight and Continuous Ridge Ventilator Showing the Advantages of the Ventilator Over the Skylight.

Ventilators are superior to top-hung continuous windows in monitor and sawtooth installations.

In a nonferrous foundry it is common practice to erect a baffle or hood over the crucibles or electric furnaces and exhaust the fumes by fan ventilation. The required air changes in the section of the baffles should be based on 120 air changes per hour.

In the pouring section of the nonferrous foundry, 20 air changes per hour are necessary and fan ventilators should be used to carry away the lead fumes present.

Laundry

Laundry buildings are hot and humid and therefore require 18 to 20 air changes per hour. Hoods should be installed over the large mangles. Proper distribution of incoming air is essential. Fan ventilators should be used because they will give a more even ventilation control during the hot and cold seasons. All ventilators should have dampers.

Machine Shop and Erection Shop

These two buildings generally adjoin each other and operate as a unit. The erection shop is always high. Two air changes per hour are required. Natural-draft ventilators may be used. Sometimes there is a section in the erection or machine shop where a great deal of welding is done. In that welding section, 10 air changes per hour are necessary, using fan ventilators.

Paint Shops

Where equipment is painted with ordinary paint, 10 air changes per hour with a good supply of air inlets are necessary to dry the paint more quickly. Natural-draft ventilators may be satisfactory with ridge ventilators being used in some cases. Where equipment is painted with other than ordinary paint, ventilation is necessary to the extent of 60 to 100 air changes per hour with fan ventilators equipped with hoods and having explosion-proof motors.

In this connection refer to Proceedings, Vol. 45, 1944, page 154, report on assignment 3: Design of facilities and equipment for spray painting of rolling stock.

Roundhouses

If a steam locomotive stands properly under its smokejack, there should be no necessity for ventilation improvements. The louvres so often used in roundhouses should be eliminated because there is no control during the change of seasons. Ridge-type ventilators with dampers located on the upper part of the roof and over each stall to give 25 to 35 air changes an hour should be used.

Recommendations should be made for the testing of materials to be used in the manufacture of the ventilators on the various railroad shops. Most railroad companies have their own testing organizations and these should be consulted.

Shop Offices

The fans of fan ventilators should preferably be operated at a low speed, thereby eliminating the noise created by the fans at high speed.

General

The drawing gives a complete picture of the present philosophy for better ventilation of shop buildings, including the elimination of monitor construction and especially of top-hung sash for ventilation.

A ventilator, regardless of the material of which it is made, should be constructed on a definite engineering principle. It should have certain established ratios between the stack dimensions and its height and width; also, it should produce as straight a flow

Workmanship

Tubing shall be installed in straight lengths as far as possible and where bends are nceessary the radius of the bend shall be not less than six times the inside diameter of the tubing.

Tubing shall be cut square to length and burr removed. Contacting surfaces shall be thoroughly cleaned and all dark spots shall be removed. Soldered joints shall be made by heating the fitting with a torch to an even temperature so that solder will flow evenly but will not burn. All soldered joints shall be made using a noncorrosive flux.

Flared joints shall be made using approved flanging and sizing tools of the appropriate size. The use of wicking or other fillers will not be permitted in making flared joints.

Manufacturers Markings

On tubes 3/8 in. in diameter and over, the trademark of the manufacturer and a mark indicative of type shall be permanently marked on each tube at intervals not greater than 1½ ft.

All fittings shall be clearly marked with the manufacturers trademark and shall clearly indicate the size thereon.

Pipe Covering

Pipe covering shall be as specified in AREA Specifications for Plumbing.

General Conditions

All materials entering into the work and all methods used by the contractors shall be subject to the approval of the engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The general conditions as given in Section I of this specification shall be considered to apply with equal force to this section of the specification.

Pages 6-67 to 6-74, incl.

Ornamental and Miscellaneous Metal Work

1930

Paragraph 3, unit stresses. Revise working stresses for "steel, rolled" to read: Tension, 20,000; compression, 20,000; shear, 15,000; bearing, 32,000."

Revise next to last paragraph under the table to read as follows:

Columns of any of the above metals shall be proportioned by the formula for structural and rivet steel in compression given under paragraph 12 of Structural Steel and Iron, Committee 6, Buildings, in the ratio that its working stress bears to 20,000.

Paragraph 4, revise to read:

Rolled steel shall be made by the open-hearth process and otherwise shall comply with the current specification of the ASTM, Serial Designation A 7.

Cast steel shall comply with current specification of the ASTM. Serial Designation A 27, Grade U-60-30.

Where copper bearing steel is specified, it shall contain not less than 0.2 percent copper.

Paragraph 5, revise to read:

Wrought iron shall comply with current specification of the ASTM Serial Designation A 41 for bars, and ASTM A 42 for plates.

of air as possible towards the exhaust and eliminate any unnecessary inside louvres. No wind should enter the ventilator from the bottom when it is deflected from the roof.

To obtain the best results in regard to capacity and all-around utility, the following dimensions and ratios should be included in any ventilator that is being used on railroad buildings, and will give assurance to the railroad management that the properly constructed roof ventilator is being installed. The ratios are as follows:

> The total height of the roof ventilator should not be less than 1.8 times the diameter of the ventilator stack. The total width of the roof ventilator should be 2 times the diameter of the ventilator stack and the exhaust area outlet should not be less than 3 times the ventilator stack area.

Of course, in all cases care shall be taken to see that local, state and other governing codes, laws, etc., are complied with in applying the above outlined requirements.

Your committee submits for adoption and publication in the Manual the Specifications for Copper Tubing which your committee presented as information at the annual meeting in 1948—Proceedings, Vol. 49, 1948, pages 121 and 122.

SPECIFICATIONS FOR COPPER TUBING

General

The contractor shall furnish all labor, materials, tools and equipment, except as may be otherwise noted, necessary to entirely complete the copper tubing installation covered by the specifications and as shown, called for or implied on the drawings.

Materials

Copper tubing shall be clean and free from cracks, seams, slivers, scale and other surface defects and shall conform to the current ASTM Designation B-88.

Solder used in making soldered joints or connections for hot water heating and plumbing shall be "50–50" tin-lead solder conforming to current ASTM Designation B-32 Alloy Grade 50A; and solder used for solder joints in tubing for other uses shall be of composition suitable for the installation for which it is to be used.

Fittings shall be cast bronze solder type, wrought copper solder type or cast bronze flared tube type fittings. Valves shall be cast bronze solder type or cast bronze flared tube type Each fitting and valve shall have the size and the manufacturer's name cast or stamped in the metal. Cast bronze valves and fittings shall be of uniform quality, free from porosity cracks, shrinkage, defects, and the casting shall conform to current ASTM Designation B-61.

Use Classification

Underground or solidly enclosed lines shall be extra heavy class "K" annealed tubing. Fittings, joints and valves in underground installations shall be cast bronze flared tube type.

Tubing inside structures may be class "L" annealed or hard drawn copper tubing with cast bronze solder type valves and cast bronze or wrought copper solder type fittings.

Tubing for use in exposed work shall be in straight lengths while coiled tubing may be used in unexposed locations.

Passing a 1-in. screen, not less than 95 percent.
Passing a ¾-in. screen, not less than 25 percent or more than 75 percent.
Passing a ¼-in. screen, not more than 5 percent.

6. Sand

The sand for the binder and surface courses shall be clean, hard, durable grains, free from clay, loam or other foreign matter.

The sand for the binder course shall all pass a ¼-in. sieve.

The sand for the surface course shall conform to the following grading:

Passing a No. 4 sieve—100 percent.
Passing a No. 4 sieve and held on a No. 10 sieve—0 percent to 5 percent.
Passing a No. 10 sieve and held on a No. 40 sieve—14 percent to 50 percent.
Passing a No. 40 sieve and held on a No. 80 sieve—30 percent to 60 percent.
Passing a No. 80 sieve and held on a No. 200 sieve—16 percent to 40 percent.
Passing a No. 200 sieve—not over 5 percent.

7. Aggregate

Stone or slag for the surface course shall have the same qualities as that specified for aggregate for the binder course and shall meet the following grading requirements:

Total Percent Passing Square Openings

Opening	*Percent*
½-in.	100
⅜-in.	90–100
No. 4 sieve	10–35
No. 8 sieve	0–5

8. Asphaltic Cement

Penetrations specified for asphaltic materials are in hundredths of a centimeter.

The asphaltic cement shall be either a refined solid native lake asphalt softened with a liquid petroleum flux or a refined petroleum asphalt derived by the steam distillation of asphaltic petroleum. The asphaltic cement shall be homogeneous, free from water and decomposition products, and shall have the following characteristics:

Flash point not less than 175 deg. C. (347 deg. F.)
Penetration at 25 deg. C. (77 deg. F.), 100 g. 5 sec., 25–75.
Ductility at 25 deg. C. (77 deg. F.) not less than 40 cm.
Loss at 163 deg. C. (325 deg. F.) 5 hours, not more than 3 percent.
Penetration of residue of above at 25 deg. C. (77 deg. F.), 100 g. 5 sec., not less than 50 percent of original penetration.
Bitumen soluble in carbon tetrachloride, not less than 99 percent.
It shall have a float test of not more than 10 min. at 65½ deg. C. (150 deg. F.).

If the above asphaltic cement is composed of refined lake asphalt softened with liquid petroleum flux, it shall contain not more than 40 percent of such flux and not less than 3 percent of nonbituminous matter naturally occurring therein. The refined lake asphalt shall have the following characteristics:

Water, none.
Penetration at 25 deg. C. (77 deg. F.), 100 g. 5 sec., not over 30.
Bitumen soluble in carbon tetrachloride, not less than 99 percent.
Residual coke (ash free), not more than 15 percent.
Paraffin scale (Holde), not more than 0.1 percent.
Sulfur, not less than 3.0 percent.

Paragraph 6, revise to read:

Cast iron shall comply with current specification of the ASTM, Serial Designation A 48.

Pages 6–136 to 6–140, incl.

Sheet Asphalt Pavements

1931

Delete the entire specification and substitute the following:

ASPHALTIC CONCRETE PAVEMENTS

1950

1. General

The contractor shall furnish all labor, materials, tools and equipment except as otherwise noted, necessary to complete the pavement as hereinafter specified and as shown or implied on the drawings.

2. Description

The pavement shall consist of a subgrade, a concrete foundation, a binder course, and a surface or wearing course.

The binder course shall be 1½ in. thick and shall consist of coarse stone or slag aggregate, and sand, uniformly mixed with asphaltic cement and laid upon the concrete foundation.

The surface course shall be 1½ in. thick and shall consist of stone or slag aggregate, and sand, uniformly mixed with asphaltic cement and laid upon the compacted binder course.

3. Grading, Subgrade and Foundation

The grading, subgrade and concrete foundation shall be constructed in accordance with the current specifications of the AREA for concrete pavement, except that joints shall be omitted and the concrete finished to a rough, even surface 3 in. below the finished surface of the pavement. A good existing foundation may be used.

4. Curb and Gutters

The curb or the curb and gutter, as the case may be, shall be built of concrete in the location and to the elevations, sizes and cross sections shown on the drawings.

All cement and concrete materials and workmanship shall comply with the specifications for concrete as given in Section IV of these specifications.

MATERIALS

5. Stone or Slag for Binder Course

The stone for the binder course shall be clean, hard, crushed stone, free from shale, soapstone or soft stone.

The broken slag shall be composed of air cooled blast furnace slag and shall be clean, sound, durable, reasonably uniform in density and free from an excess of thin or elongated pieces.

Stone and slag shall be graded in size to comply with the following requirements:

Passing a 1¼-in. screen, not less than 100 percent.

any portion of the binder surface shall show an excess of asphaltic cement such portion shall be immediately removed and replaced with a properly mixed portion of the hot binder course material, subject to the approval of the engineer.

The upper surface of the completed binder course shall be parallel with and 1½ in. below the finished surface of the asphalt pavement.

11. Asphaltic Concrete Surface Course—Mixing

The surface course shall consist of a mixture of the asphaltic cement, sand, stone, or slag, specified herein before mixed in such proportions that it shall conform to the following limits by weight.

Bitumen (soluble in carbon disulfide), 6 to 9 percent.
Aggregate retained on a No. 6 sieve, 40 to 60 percent.

The stone or slag and sand shall be heated in suitable appliances to a temperature not higher than 375 deg. F. and stored in separate bins. The hot sand and stone or slag shall then be weighed separately and mixed together. The hot asphaltic cement shall be added and mixed until all particles of aggregate are thoroughly and uniformly covered. The asphaltic cement shall be heated to a temperature not exceeding 300 deg. F. and the entire mixture kept in continuous agitation during the entire operation.

The heating kettles shall be free from foreign matter before use and shall be equipped with suitable agitators to keep the asphaltic cement at a uniform and proper consistency.

12. Surface Course—Placing

Before dumping or laying the wearing mixture, the surface of the binder course shall be dry, clean and free from dust or other foreign matter, and any portions of the binder course which may have been dsiturbed or damaged in any way, shall have been removed and replaced with new material.

The wearing mixture shall have a temperature immediately before dumping of not less than 225 deg. F., nor more than 350 deg. F., and shall be dumped so that no part of the load is nearer the completed part of the wearing course than the distance along the length of the pavement it will occupy when spread.

Immediately after dumping, the surface course material shall be put in place with hot shovels and spread while hot and thoroughly combed out with hot rakes to receive its final compression by rolling or spread and finished by a mechanical finishing machine.

The loads of asphalt mixture shall not be dumped on the binder course any faster than they can be properly handled by the shovelers. The shovelers shall not distribute the dumped material any faster than it can be properly handled by the rakers. The rakers shall not be permitted to walk or stand in the hot mixture while raking, except when necessary to correct errors in the first raking. Immediately after raking, the mixture shall be compressed with hot iron tamps at all places inaccessible to the rollers. In all other places the mixture shall be compressed with self-propelled rollers as soon after being raked as it will bear the rollers without undue displacement or hair cracking.

Compression shall be obtained by first smoothing the surface with a selfpropelled roller weighing not less than 10 tons and having a weight of not less than 200 lb. per in. of width of driving roll.

The rollers shall be operated at a speed of approximately 100 ft. per min. and at no time shall they be permitted to exceed a speed of 150 ft. per min. When necessary to prevent the hot mixture from sticking to the roller a small amount of water may be used to moisture the roller, but excessive amounts will not be permitted.

The liquid petroleum flux to be used with the native lake asphalt shall be any steam-refined residum of the heavier and higher boiling portions of petroleum. It shall be free from decomposition products and shall have the following characteristics:

Water, none.
Specific gravity at 25 deg. C. (77 deg. F.), between 0.92 and 1.02.
Flash point, not less than 175 deg. C. (347 deg. F.).
Penetration at 25 deg. C. (77 deg. F.), 50 g. 1 sec., not less than 350.
Bitumen soluble in carbon disulfide, not less than 99½ percent.

Each bidder shall state specifically in writing the approximate proportions of the individual constituents of the asphaltic cement which he proposed to use and upon request shall furnish a 1-lb. sample of said asphaltic cement. If he proposed to prepare the asphaltic cement at the paving plant then, in lieu of the above, he shall furnish a 1-lb. sample of each constituent. The bidder shall furnish a written statement of the source and character of each constituent. Bids not in compliance with this requirement will be rejected as irregular.

CONSTRUCTION

9. Binder Course—Mixing

The binder course shall consist of a mixture of the asphaltic cement, sand, stone or slag specified hereinbefore. The mixture shall be in such proportions that it shall conform to the following limits by weight:

Bitumen (soluble in carbon disulfide), 4 to 7 percent.
Aggregate retained on a No. 6 sieve, 50 to 60 percent.

The stone or slag and sand shall be heated in suitable appliances to a temperature not higher than 375 deg. F. and stored in separate bins. The hot sand and stone or slag shall then be weighed separately and mixed together. The hot asphaltic cement shall then be added and mixed until all particles of aggregate are thoroughly and uniformly covered. The asphaltic cement shall be heated to a temperature not exceeding 300 deg. F. and the entire mixture kept in continuous agitation during the entire operation.

All heating kettles shall be free from foreign matter when they are charged.

10. Binder Course—Placing

The surface of the concrete base on which the binder course is to be laid shall be dry and free from foreign matter and no more binder course material shall be laid than can be covered by the surface course in 2 days.

The material shall be delivered in trucks with tight bodies and covers of canvas or other suitable material.

The material shall have a temperature immediately before being dumped of not less than 225 deg. F. nor more than 300 deg. F. and shall, when dumped, be immediately raked with hot rakes to a uniform surface or spread and finished by a mechanical finishing machine.

When the temperature of the air is below 30 deg. F., special provision shall be made for heating the concrete base and for keeping the heated surfacing matrials from becoming cooled too rapidly while applying.

All contact surfaces of curbing, gutters, manholes, etc., shall be painted with hot asphaltic cement before any binder mixture is laid against them.

The rolling shall be done with a self-propelled tandem roller weighing not less than 200 lb. per in. of width of driving roll and shall closely follow the spreading, and where

Pages 6–209 to 6–210, incl.

Floors for Railway Buildings

1926

In paragraphs 5, 8 and 14 delete the words "asphalt block" also delete the last sentence of paragraph 15.

Pages 6–214 to 6–216, incl.

Passenger Stations

1948

Paragraph 3, revise the table giving intensities of illumination to read as follows:

	Footcandles
Waiting Rooms	15 to 25
Rest rooms and smoking room	15 to 25
Ticket office	20 to 30
Concourse	5 to 10
Baggage room	5 to 10
Train platforms	5 to 8
Toilet and wash rooms	8 to 10

Also insert a paragraph as follows:

Special or concentrated lighting should be installed as required to meet special conditions.

Paragraph 5, delete the paragraph and substitute the following:

In all stations coves should be provided at floor lines; all heads and angles that may collect dirt should be avoided.

In toilet rooms, floors and wainscoatings should be made of impervious materials that can be easily kept clean by washing. The rooms should be well ventilated and lighted.

Paragraph 6, delete the paragraph and renumber paragraph 7 as No. 6. Add a new paragraph, number 7.

7. Interior Finish

Interiors of passenger stations should be finished with materials and in colors that will provide a pleasing and attractive appearance, without sacrificing durability and reasonable maintenance costs.

Special attention should be given to floor finishes in order to provide floors that will be resilient, durable, and easy to keep clean.

Page 216.1

Location and Design of Signs for Passenger Stations

1948

Insert a new paragraph between the fourth and the last paragraph on the page to read as follows:

Consideration should be given to designing the signs to the spacing of the letters. Signs to be seen at night should be effectively illuminated.

The rolling shall be done at a rate not to exceed 250 sq. yd. per hour per roller. Rollers must be kept in continuous operation as nearly as practicable and in such manner that all parts of the pavement shall receive substantially equal compression. All rollers shall be kept in good condition and must be operated by competent and experienced operators.

Any part of the unrolled surface course in place which has been stepped on shall be removed, discarded and replaced with material in proper condition.

Before any additional hot surface mixture shall be placed against cold edges, the edges shall be prepared by brushing them with hot liquid asphalt and the new work applied before the edge has become hardened.

Joints between old and new pavements or between successive day's work shall be carefully made in such manner as to insure a perfect and continuous bond between the old and new surfaces.

The finished pavement shall have a contour substantially conforming to the grade and shall be free from any depression or elevations greater than 3/8 in. from a true surface as measured between any two points 6 ft. apart and parallel to the curb.

13. Tests

All methods of testing shall be made in accordance with the standard specifications and methods of the American Society for Testing Materials.

14. Adjusting Existing Structures

Manholes and catchbasin covers, valve boxes and similar existing structures within the area to be paved shall be adjusted by the paving contractor to come flush with the pavement surface.

15. Guarantee

It is hereby understood and agreed that the paving contractor guarantees the material furnished and used and the workmanship employed in the construction of said improvements to be of such quality and character as to insure the same to be free from all defects and to remain in continuous good order and condition satisfactory to the engineer for a period of 2 years as above set forth.

The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work as the engineer may direct, without additional charge or cost to the railroad company.

In case the paving or any part thereof is on public property where a city ordinance or other ruling requires a maintenance bond, the contractor shall furnish within 10 days after the contract is let a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by the ordinance or ruling.

16. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section I of this specification shall be considered to apply with equal force to this specification.

the approach tracks for the outside operations. With the running maintenance servicing tracks extending through the building, the serviced locomotive can be taken out of the shop, without any interruption to the flow of locomotives following through the servicing operations. For the achievement of maximum efficiency in servicing, the primary purpose of constructing specialized diesel shop facilities, this factor is of paramount importance.

Tracks assigned to heavy repairs need not be given this consideration since the movements in and out of these tracks are comparatively infrequent.

Inspection Pit and Servicing Areas

It is generally agreed from experience in inspection and servicing, that the "between run" servicing operations can best be performed on an inspection pit, served by both a depressed floor and a high floor level, or working platform.

Inspection pit details are varied, but a depth of 4 ft. below top of rail seems to generally accepted. The pit length should be from 10 ft. to 25 ft. greater than the overall length of the longest locomotives to be serviced. Drainage should be provided with either floor drains or sumps located at proper intervals along the length of the pit. The pit walls, of reinforced concrete, are either carried to the height of base of the rail or to a level of the depressed floor area, with steel columns extended to the height of base of rail for track support. The latter detail is a commendable one, since it affords a positive method of draining the floor (crowned at the center) into the pits, as well as aid in pit lighting and of providing access into the pit along its entire length. The distance between centers of parallel inspection pits varies from 18 ft. to 26 ft. This dimension is established by the desired width of high level platform, except when a release track is introduced between pits, requiring a minimum of approximately 23-ft. track centers.

The depressed floor along the inspection pits places the mechanic at proper height with the locomotive for inspecting and making repairs to trucks, braking systems and other underbody equipment. The elevation of this depressed floor area varies from 2 ft. to 2 ft. below the top of rail on the inspection pits. The floor should be well drained. and constructed with a surface easily cleaned.

The provision of elevated working platforms in the area between adjacent servicing track, as well as the outer sides of these tracks, is generally agreed to be a necessary feature in the diesel locomotive shop. The height of these platforms with respect to top of rail is most generally 4 ft. 8 in. or 4 ft. 11 in., with some constructed at 5 ft. 6 in. The distance from the edge of the platform to centerline of track must be held to a minimum of 5 ft. 6 in. or as otherwise necessary for proper clearance of the equipment to be served. It is recommended that platforms be constructed of noncombustible material, usually consisting of steel columns and beams and a reinforced concrete, steel grating or steel plate decking. Due to spillage of lubricating oil and greases, steel plate decks, even though with checkered surfaces, become very slippery and a safety hazard. Platforms should be provided with removable handrails along all edges, consisting of pipe supports with chains between them. Access to the working platforms from normal top of rail level floors and depressed level floors, shall be provided by means of stairs and ramps at the ends and at intermediate points. Access from one platform to another is most desirable and this can be accomplished by means of bridges. Such bridges must be removable and can be of a simple form of "gangplank" and set into place and removed with a lightweight motorized monorail hoist. There is also manufactured an elevator type bridge having rails in the bridge floor, which can be depressed into the inspection pit when necessary to move locomotives past the line of platform bridge crossing.

Report on Assignment 3

Shop Facilities for Diesel Locomotives

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This report is presented as information to supplement previous reports on this assignment which appeared in the Proceedings, Vol. 44, 1943, page 235 and Vol. 46, 1945, page 87.

In the previous reports on this assignment the character and extent of the facilities necessary for the repair of diesel locomotives, are discussed in considerable detail. Because the diesel locomotive consists of an assemblage of individually replaceable and interchangeable units of equipment, repairs are primarily on a "progressive" basis requiring servicing facilities planned for this express purpose. To further illustrate, the replacement of a diesel engine crankshaft is an operation requiring many shop hours to complete, yet the entire diesel engine may be removed from the locomotive and replaced with a spare engine in a matter of hours, permitting the locomotive to return to service with a minimum of lost time. Such a service operation requires equipment of a capacity to handle an engine weighing from 25 to 30 tons, as well as a separate space for performing the specialized engine overhaul. Upon completion of the overhaul, the engine will become a spare unit. A similar cycle of operation is applied to traction motor replacements, wherein the complete truck is removed and replaced with a spare unit and the truck then separately repaired without any loss of service from the locomotive.

Heavy Repair and Running Maintenance

As outlined in one of the previous reports on this assignment (Proceedings Vol. 44, 1943, page 236) diesel locomotive repairs can be divided into two general classifications; heavy repair and running maintenance. A diesel shop falling within the classification of a "heavy repair shop" would be one equipped to handle all phases of diesel locomotive repair and overhaul. The "running maintenance shop" would be one limited to normal terminal servicing and such operations which would not require heavy hoisting equipment and extensive tool layout.

Heavy Repair Shop Planning

The planning and design of the "heavy repair shop" for the servicing of diesel locomotives has become a subject of much importance and study with the growth of this type of power, which in the case of many railroads, has approached complete replacement of steam power. In order to satisfy the interest and quest for additional information, this report will discuss the elements of design to be considered in the planning of diesel shops, devoted to both running maintenance and heavy repairs.

The primary consideration in diesel shop planning is that the tracks be parallel and it is recommended that those tracks which are to be assigned for terminal servicing or running maintenance, be through tracks. It is a basic consideration that the diesel locomotive be serviced on a production line routine, with all sanding, fueling, watering and washing being accomplished on the lead or approach tracks to the shop building. The locomotive then enters the building for the inside inspections, lubrication and minor repairs. While this locomotive has moved into the shop, other units have followed onto

and the various pieces of equipment are removed to areas provided for specialized servicing and repair. The traction motors are transferred to the electric shop, brake cylinders to the air brake shop, wheels to the wheel shop, etc.

Many of the truck repair operations can be handled in facilities which may already be available in the railroad terminal. The brake and wheel work can well be handled in shops provided for freight and passenger car equipment. However, the exception is in the repairing of traction motors, which demands specialized equipment and mechanics for electrical work of a degree not heretofore required on a steam railroad.

Electrical Shop

Many railroads do not attempt to provide for complete electrical repairs in their diesel shop facilities because these call for an extensive outlay of equipment manned by highly skilled and specialized electrical mechanics. It is, however, important that there be available a shop for limited servicing of electrical equipment to the extent of dissembling, inspecting and reassembling traction motors and generators. Special machines in the electrical shop might well include a lathe for turning down commutators, a baking oven for drying out electrical equipment and a balancing machine. Provision should also be made for meter testing equipment, although this may be of a portable nature to enable the making of tests from the working platform without removing the meters from the locomotive.

Engine Repair Shop

The engine repair shop is primarily for tearing down and reassembling engines, which operation is accomplished most satisfactorily in an area separated from the contamination by the main shop activity. The room should adjoin an area served by an overhead crane from which an engine can be set on a "dolly" and wheeled into the engine shop. As the engine work requires the handling of heavy parts, hoisting equipment of five-ton capacity is invaluable.

Small Parts Reconditioning Shop

The small parts reconditioning shop is fairly well defined by the label placed on this area. Since much of the equipment reconditioned is removed from the locomotive at the working platform level, it is most logical that this facility be located on the same level. The equipment commonly installed for carrying out the various operations includes a valve grinder and refacer, grinding and buffing wheels, small press, drill press, small lathe, liner hone, magnaflux machine, magnaglow machine for valves, small monorail hoist for handling heads and work benches, tool cabinets, etc. An adequate number of electric and air outlets should be provided for convenience of operation.

Filter and Parts Cleaning

A companion to the electrical shop and the engine servicing shop is the filter and parts cleaning room, the construction of which requires more exacting consideration than do the other rooms. It is most important that the cleaning room be isolated from other areas, since the steam and moisture from the cleaning tanks is most injurious to finely machined engine and electrical parts exposed in overhaul operations. Ventilation hoods should be placed over the cleaning vats and walls or ceiling areas exposed to cold temperatures and insulated to prevent condensation of moisture laden air. Overhead cranes or hoists should be provided for transferring filters and parts through the various vats, drying ovens, oilers, etc. Attention shall be given to providing adequate floor and equipment drainage that is carried through an oil separator before discharging into the sewer system.

Truck Replacement

The proper equipment and facilities for changing trucks and wheels, within the shortest period of time, comprise one of the most important demands placed upon the diesel shop, since such changes, if found necessary upon inspection, must be made within the time allowed for servicing. Rather than replace a single pair of wheels or traction motor, it is customary to replace the entire truck unit with a spare truck and thus quickly release the locomotive for service.

The simplest form of equipment for truck changes, and that used in the earlier days of diesel locomotive servicing, is the transfer table. However, as the locomotive jacking pads are located on the line of center of the trucks, the jacks become an obstruction to removal of the truck. Unless overhead suspension type body supports can be provided, the transfer table does not adapt itself as the best type of truck handling equipment.

The drop table, with either electric or hydraulic hoisting and racking motive-power, has become the most generally accepted equipment for the truck changing operation. Requirements as to the capacity of the drop table are dependent upon the types of locomotives to be serviced. Most generally those of 100-ton capacities are used to service present freight and passenger locomotives. Table tops 17 ft. in length are required for 4-wheel trucks and tops 23 ft. long for 6-wheel trucks. These are minimum lengths for the present trucks now used, but in order to allow for possible increases in truck lengths a few railroads are installing tables 26 ft. in length.

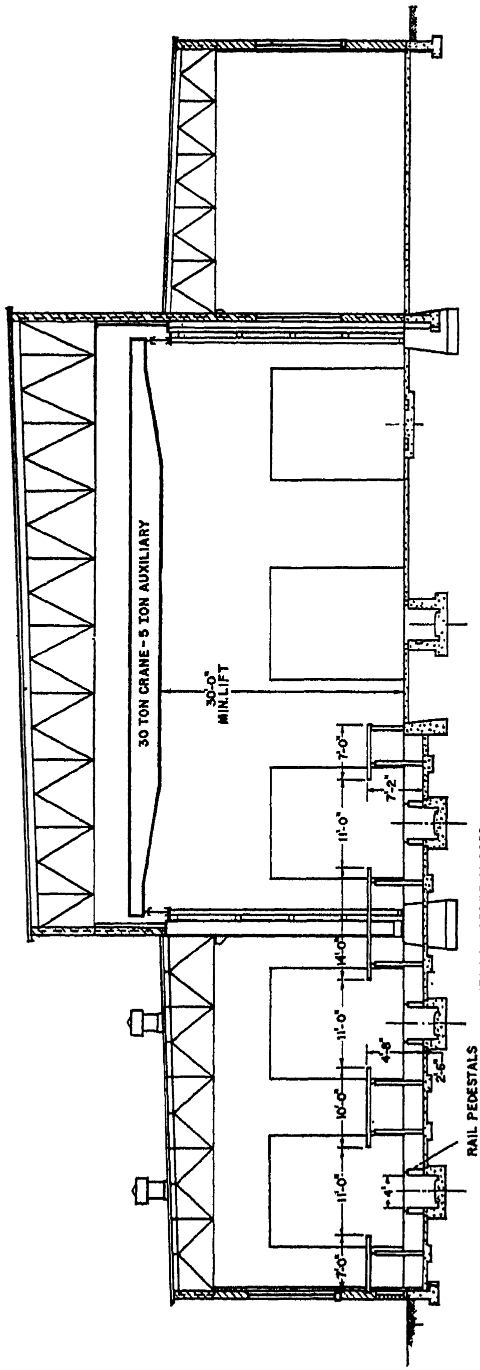
In the planning of the diesel locomotive shop layout, it is important for the designer to carefully consider the location of release tracks. Considerable economies in construction can be realized if release tracks can be arranged between each pair of tracks, i.e., in a 4-track shop, release tracks be provided between tracks 1 and 2 and between tracks 3 and 4. Such an arrangement will avoid the necessity of lowering the table, its top and the truck below another table top to reach the release track, and a drop table pit depth of approximately 8 ft. to 10 ft. is sufficient. With any other release track arrangement, a truck must be lowered below an adjoining table top, necessitating a pit depth of approximately 16 ft. to 18 ft. By reason of the multiple increase of pit costs as the depth increases, proper location of release tracks can effect considerable economies in construction of the proposed diesel shop layout.

Necessary for use with the drop table, is the body support, either a box girder above the floor or a box girder below the floor with only a post type support above the floor. With drop tables more than 23 ft. in length, the body support rests should have longitudinal adjustment, as fixed center rests will result in placing the second truck of certain locomotives on the table top. Also available are types of body supports which are suspended from construction above, but this type is not as practical nor as generally used.

The investment in the installation of drop table hoisting equipment and body supports, can be justified at those points where major diesel locomotive servicing and repair work is done on enough units to effect savings in labor as well as in the time of returning locomotives to service. At those terminal points where locomotives are only serviced and turned, there may be occasion for truck removal as an emergency measure. At such location, jacks should be provided for truck removal and repair.

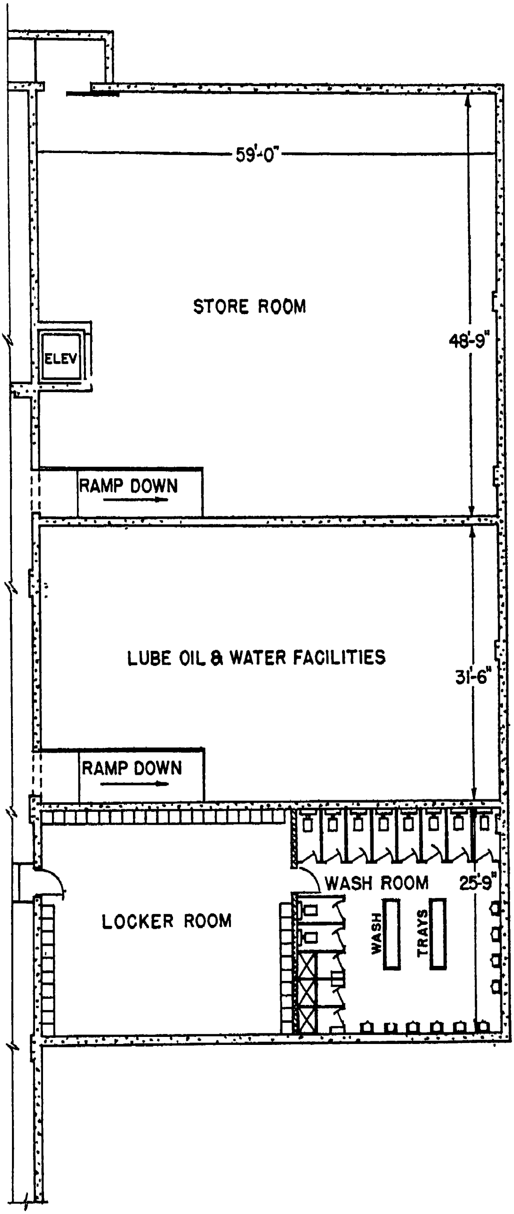
Truck Servicing and Repair

Servicing and repairs to trucks are made in a systematic manner, usually in an area somewhat removed from the area in which the locomotive is serviced. Such an area should be provided with a truck washing platform, for cleaning prior to the overhaul. Following the pattern of the entire locomotive overhaul, the truck is dissembled



SECTION A-A

Heavy Repair Shop for Diesel Switcher Locomotives.



Heavy Repair Shop for Diesel Switcher Locomotives.
Service Facilities on Lower Level.

pit heating for employees' comfort and defrosting the underside of the locomotive is an important consideration.

In addition to heating fresh air introduced into the building to replace that consumed by engine combustion and exhaust units, space heating units equivalent to natural building heat losses, must be installed to heat the building when the exhaust supply ventilation system need not be operated.

As a result of tests conducted by the U. S. Department of Interior, Bureau of Mines, in the Cascade tunnel of the Great Northern Railway during October 1944, valuable data were obtained for the calculation of a diesel shop ventilation system. The diesel locomotive used in the tests was an Electro-Motive 5400 hp., 4-unit freight locomotive, and gas samples of engine exhausts were taken at idling speed (275 rpm.), ¾ speed (650 rpm.) and full engine speed (800 rpm.). The test developed that 0.375 lb. of fuel is consumed per horsepower-hour and 434.4 cu. ft. of exhaust gas produced for each pound of fuel consumed. The scavenging and intake air supplied through blowers was 4.27 cfm. per horsepower. Inasmuch as horsepower will vary as the speed, the base horsepower at idling speed (275 rpm.) will be 0.344 of full speed (800 rpm.) horsepower. Samples of exhaust gases taken at the exhaust outlets developed the following:

	Composition of Samples (Percent of Volume)					*Oxides of Nitrogen (Parts Per Million)*
Engine Operation	*Carbon Dioxide*	*Oxygen*	*Carbon Monox.*	*Hydro-Carbons*	*Nitrogen*	
Full throttle (800 rpm.)	6.52	11.93	.20	0.06	81.29	1117
¾ (650 rpm.)	4.52	14.83	.03	0.00	80.62	936
Idling (275 rpm.)	.68	19.98	.01	0.00	79.33	145

The following is a typical calculation to determine the building exhaust requirements. similar calculations to be carried out for the maximum number of locomotives which will run in the house at one time. In idling one three-unit 6000-hp. diesel the total engine exhaust gases would be:

$$\frac{6000 \times .375 \text{ lb.} \times 0.344 \times 434.4}{60} = 5604 \text{ cfm.}$$

As the ventilation system must satisfy either code regulations or accepted good practice, we shall consider a typical code requirement which allows 10 percent exhaust gas concentration or 10 parts per million oxides of nitrogen concentration. To satisfy the limit of 10 percent exhaust gas concentration would require dilution with fresh air of 10 times the exhaust volume or approximately 56,000 cfm. The governing factor is in reducing the oxides of nitrogen concentration to less than 10 parts per million. From previous exhaust gas analysis we find existance of 145 parts oxides of nitrogen at idling speed, requiring 15 times the volume of fresh air, or approximately 84,000 cfm. exhaust.

It will, of course, be necessary to supply heated outside air to supply combustion air, as well as to replace the air exhausted (determined above). The combustion air requirements for the 6000-hp. diesel will be as follows:

$$4.27 \times 0.344 \times 6000 = 8808 \text{ cfm.}$$

The 84,000 cfm. exhaust plus the 8808 cfm. air consumed in combustion requires a minimum of 92,000 cfm. heated supply air.

Due to the limited amount of time allowed for the servicing of the diesel locomotive, it is not possible to allow engines to cool off, and mechanics working inside the locomotive are often subject to considerable discomfort from engine heat and fumes. Portable fans may be arranged to circulate air through the engine room to provide better working conditions for the maintenance crews.

Consideration should be given to installation of a caustic tank located outside the building to permit the removal of grease and paint from large parts which cannot be accommodated in the parts cleaning shop.

Overhead Crane Equipment

As the nature of operations in the heavy repair area of the diesel shop requires the handling of engines, generators and trucks, the overhead crane is a necessary and essential piece of equipment. Cranes with a 30 to 35-tons capacity are recommended and with a hook height of 30 ft. above top of rail to permit lifting an engine through the roof of a locomotive. To facilitate the removal, resetting and handling of smaller units a five-ton auxiliary hook is invaluable. As the lifting of floor level objects can best be controlled from the floor, and those within a locomotive from a crane cab, both pendant and cab control systems are suggested.

Heating and Ventilation

Probably the most perplexing and challenging problem to confront the designer of a diesel shop, is that of providing the best and most effective system of heating and ventilation. Reference is made to a previous report on this subject which appeared in the Proceedings, Vol. 48, 1947, page 319 which offers information on this subject. However, much study and information is being developed with regard to diesel shop heating and ventilation, but the subject is too broad to discuss in complete detail as a part of this report.

Among the problems involved in heating and ventilating the diesel shop are those of removing the exhaust gases from locomotives on test and tune-up, replacing combustion air consumed by the engines with tempered fresh air, and the replacement of heat loss through the building.

At an outlying terminal where one particular type of diesel locomotive may be housed and serviced, a simple type of telescopic stack fitted with a rain hood or syphon ventilator, may be provided for each exhaust port of the locomotive. When engines are to be run while in the house, the stacks are extended to cover the exhaust port, the exhaust having sufficient velocity to expel itself. Unit heaters, generally used for heating such buildings can be provided with a duct having an outside air intake and adjustable damper for either introducing 100 percent fresh heated air or 100 percent recirculated air.

The problem becomes a real challenge in the principal terminal diesel shop where the locomotives to be serviced and repaired are of many types and different manufacture. The individual exhaust stack is no longer practical and the problem is one of providing a mechanical ventilation system. If the overhead crane does not operate in the servicing area in which most engine testing is done, it is possible to provide hoods on the center line of tracks and by means of power exhaust units, collect the gases close to the source and expel them from the building. Another general method of providing ventilation in servicing areas, as well as crane bay areas, is to install power exhaust units in proper locations throughout the roof deck. In connection with the latter, roof areas may be divided into cells by facing one side of roof trusses with cement asbestos board, the cells confining the gas to an area served by individual exhaust units, permitting operation of individual ventilators as required.

The heated fresh air supply should be introduced into the building at the lowest point practical, to aid in the movement of air upward and outward through the roof ventilators. The air supply should be widely distributed at the lowest possible velocity to avoid discomfort to mechanics working on lower floor and platform levels. Inspection

nozzles for quick action control of oil flow. Meters may be provided to measure the quantity of oil used in servicing the locomotive. Such a dispensing system is of value in adding small quantities of oil or complete oil changes.

Oil drainage systems usually consist of a tank placed below the level of the inspection pits with connecting piping from the pits for gravity flow into the tank. Connections should be provided at intervals throughout the length of the pit for making hose connections with the engine drain. The dirty oil is pumped from the gravity storage tank into tank cars and returned to the reclamation plant.

Portable drain and lubricating oil tanks on wagons, of approximately 200 gal. capacity, should be provided for servicing locomotives in the heavy repair areas, not provided with the lubricating oil dispensing and drain oil system.

Water Supply Systems

Water supply systems in the diesel servicing shop are a most important consideration. Due to the complex nature of the steam generator on the diesel locomotive, the highest quality water is desirable for trouble free operation. Clean condensate or distilled water with a small amount of corrective treatment therefore provides an ideal water for the steam generator. Because of the excessive cost to provide this kind of water, it is often more practical to use treated steam locomotive water by supplemental treatment with a de-ionizing plant. Briefly the de-ionization process consists of passing water through two ionizing tanks which remove metallic ions and acids and then passing it through a third tank to remove carbon dioxide gas. Water treated by this method can be used for storage batteries, engine cooling systems or boiler supply.

Washing, Sanding and Fueling

The washing, sanding and fueling of the diesel locomotives are operations of the same general category and are generally performed outside of the building, on tracks approaching the servicing area. The operations of sanding, fuel oil and water supply, body and truck washing are usually combined in an area provided with spacious well-drained concrete paving and adequate lighting system.

Fire Protection

It is generally agreed that fire protection must be given consideration in every diesel locomotive repair or servicing facility, although there is considerable difference of opinion as to the type of extinguishers to provide the necessary protection. Often, a combination of several types of systems are provided for the complete protection. Standpipes located at each end of the servicing platfrom connected with a terminal high pressure water protection system are considered most effective when equippd with hose having a length equal to half the platform length, and fog nozzles. The standpipes are supplemented by carbon dioxide (CO_2) extinguishers strategically located throughout the entire shop area. The dry powder type extinguishers are particularly effective around fuel oil unloading and supply stations, but objectionable for use inside of the shop due to the possibility of the powder getting into motor windings.

Related Facilities

As in the case of shop facilities for steam power, the diesel repair shop demands, certain related facilities which are vital to efficient operation and power functioning.

In order that repair parts may be readily available for maintenance mechanics, a diesel parts store room should be established as an integral part of the diesel shop facility. As the nature of store stock consists largely of finely machined and finished

Lighting and Electrical Outlets

It is most important that the designer of the diesel shop provide for a maximum of fenestration to take advantage of all possible daylight, so essential to highest efficiency in the service and repair of locomotives. Glazing shall be done with obscure glass for the best diffusion of light. Those areas having southern exposures should be glazed with heat absorbing glass to reduce the transmission of solar heat from large glass areas.

The diesel locomotive shop permits an entirely different use of color schemes for interior painting than would be considered practical in the roundhouse for steam power. For the greatest amount of light reflection, the painting may be of pastel shades consistent with the theory of color dynamics. Handrails, stairs, crane hooks, and obstructions should be painted bright colors which will be "eye arresting" to the safety hazards which such objects may present. Piping shall be painted distinct identifying colors to aid in preventing errors in locomotive servicing or building maintenance operations.

As such a servicing and repair shop must function over a 24-hour period, the best possible artificial lighting system is a requirement of utmost importance. Every diesel shop being of individual design, a report such as this can only suggest methods for artificial lighting and recommended intensities for the various areas of operations.

Recessed waterproof fixtures along the walls of the pits have proved successful in providing proper illumination for inspection and repair under the locomotive. Lighting intensities of 20 to 30 footcandles are recommended.

Illumination of the side of the locomotive and areas under the platform can be effectively done with angle type fluorescent fixtures with glass covers to protect against dirt and moisture. Intensities of 30 to 50 footcandles are recommended.

General illumination over the servicing and repair bay areas can be accomplished by high bay incandescent or mercury vapor fixtures, sufficient to provide 20 to 30 footcandles intensity. Over the high platform and special service areas the same type of lighting with intensities increased to a level of 50 footcandles is suggested.

Convenience outlets shall be located throughout the inspection pits, servicing and repair areas for extension cords and power tools. Welding outlets should also be located at strategic points throughout the structure. Battery charging outlets should be provided as required.

Lubricating Oil Supply and Drainage

Proper lubricating oil facilities are an important function of the diesel servicing shop, as they make possible rapid oil changing and normal servicing, with a minimum of expense in handling the oil. Modern oil handling equipment contributes to keeping the premises clean and minimizes the fire hazards which usually result from old fashioned methods of bulk handling oils.

It is customary to keep each refiner's oil separate. This factor necessitates duplication of storage facilities for as many different kinds of oil as are to be used, consisting of storage tanks, pumps, dispensing stations, etc. Storage tanks of such volume as to permit purchases in tank-car lots are recommended for the larger servicing and repair shops with pumps of 25 gpm. capacities, valved and piped to permit of use in unloading tank cars and distributing from the storage tank to the dispensing stations. All electrical equipment and motors should be of explosion proof types and pumps should be controlled from the unloading and dispensing stations.

Oil dispensing stations located on the elevated platforms consist of separate hose reels for each kind of lubricating oil, with 50 ft. of hose. Each dispensing station should be located on approximately 100-ft. centers and the hoses provided with spring loaded

parts, the construction should be such as to provide a dry, dust tight, well lighted, ventilated, and temperature-controlled room.

An office area for use of the diesel shop supervisor and his clerical staff should be located adjacent to the main shop area for proper supervision and the maintaining of servicing records, preferably on the same level as the working platforms.

Adequate locker, lunch, toilet and wash facilities should be provided to meet the requirements, and so located as to be as accessible as possible.

The installation of the lubricating oil, drain oil, flushing oil and water systems, as discussed previously, necessitates an area for the installation of tanks, pumps and mechanical equipment so required. These facilities are usually located in a basement room to permit gravity flow of the drainage oil system.

Report on Assignment 5

Lumber Specifications for Railway Buildings

H. M. Church (chairman, subcommittee), F. H. Alcott, G. A. Belden, E. D. Billmeyer, H. M. Booth, E. Christiansen, C. E. Close, G. V. Coffey, D. W. Converse, V. E. Elshoff, T. J. Engle, M. C. Fleming, R. L. Fletcher, Earl Kimmel, C. E. Lex, Jr., H. C. Lorenz, I. A. Moore, J. B. Schaub, O. W. Stephens, W. E. Webb, H. C. Zepp.

This is a progress report submitted as information, which includes recommendations for yard lumber specifications for railway buildings. After publication in the Proceedings and comments and criticisms have been obtained, your subcommittee proposes to submit these specifications a year hence for adoption and publication in the Manual.

Yard Lumber Specifications for Railway Buildings

General

The grades of lumber and timber hereinafter recommended for various uses and types of construction in railway structures are divided into structural (stress-grade) lumber and yard lumber (see American Lumber Standards for Softwood Lumber).

Scope

This report covers only the yard grades of lumber. Yard grades, as defined in the American Lumber Standards for Softwood Lumber include lumber of all sizes and patterns which is intended for general building purposes.

Yard Lumber

Grades of yard lumber of the same designation are not necessarily of corresponding quality in the various species. These differences are recognized in the use recommendations shown in Tables I and II. In those few cases in dimension sizes where yard lumber is not available in that specific item, the stress-grade, in lieu of a yard grade, is shown in these tables.

Tables I and II provide a specific cross reference between each commercial grade and the corresponding commercial grading rules. In some cases alternate grades are given to accommodate the various species and types of construction. In specifying materials for specific applications, the detailed commercial grade requirements should be

examined to determine the suitability of the grade for the specific application. The grade or grades selected should be specified by the appropriate commercial grade designation. Customary commercial practices pertaining to terms of sale, shipment, inspection, etc., are given in the commercial grading rules for the various species.

Purchase Orders

Purchase orders should contain the following information:

1. *Quantity.*—In board feet, number of pieces (if of definite size and length), or linear feet (if moulding, etc., or if not of definite length).

2. *Size.*—Nominal thickness in inches, nominal width in inches and nominal length in feet (for special sizes, specify actual sizes and so designate).

3. *Grades.*—Use complete current commercial designation and indicate the current rules under which to be graded.

4. *Species of wood.*—Name species.

5. *Condition of Seasoning.*—Unseasoned, air-dried, kiln-dried, etc.

6. *Item* (Working or Pattern).—Specify whether rough (Rgh) surfaced (S4S), dressed and matched (D&M), patterned (Pat. No. ....), etc.

7. *Inspection.*—If grade marked lumber or a certificate of inspection is to be furnished, so specify.

Purpose of the Tables

The purpose of the tables is to provide specific information on available commercial grades of lumber which are most commonly used in railway building and the items for which the various grades are used.

The upper left-hand side of the table lists the species. The center portion of the table lists the more commonly used commercial grades of these species. The lower portion of the table lists the uses for which the grades and species are recommended. The upper right-hand portion of the table lists the organizations having commercial grading rules for the various species. The numbers in the upper portion of the table indicate the specific paragraph or page number of the commercial grading rule which contains the grade description of the specific grade. The table is so arranged that users may make a selection from any of the grades and species shown.

To apply the table, find the purpose for which the lumber is to be used at the lower left-hand side of the table, follow this line horizontally to the desired item of desired grade or grades, and then follow the line or lines vertically to the upper portion of the table to obtain the numbers of the specific paragraphs or pages in the grading rules of the various species. After the desired grades are decided upon, the lumber should be specified as indicated previously.

Plywood

Although not tabulated herein, standard grades of plywood are available for various uses. For detailed information on standard grades, see the following:

*Douglas Fir Plywood—Commercial Standard CS45–48
*Hardwood Plywood—Commercial Standard CS35–47
*Pine Plywood—Temporary Standard TS48–81

* Available from Superintendent of Documents, U. S. Printing Office, Washington, D. C.

Report of Committee 27—Maintenance of Way Work Equipment

R. K. Johnson, *Chairman,*
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Edgar Bennett
R. E. Berggren
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A. J. Flanagan
Bernard Geier
C. H. R. Howe
N. W. Hutchison
E. C. Jackson
A. A. Keever
W. F. Kohl
Jack Largent
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Francis Martin
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R. D. Timpany
S. E. Tracy
E. G. Wall
A. H. Whisler
F. E. Yockey
F. F. Zavatkay

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

AREA Bulletin 484, December 1949.

2. Each manufacturer shall design his motor car for the maximum practicable interchangeability of the following parts and accessories with those of any other manufacturer.

(a) *Fuel Lines.*—Low pressure hose and fittings per details in Fig. 2701 shall be used at the fuel tank end and at the carburetor or fuel pump end of the fuel line. When necessary, annealed copper tubing, or equal, of not less than 0.032 in. in wall thickness, ¼ in. outside diameter, with fittings per details in Fig. 2701, shall be used between fuel line assemblies.

(b) *Fuel Strainer.*—Sediment bowl, and strainer with shut-off needle valve, per Fig. 2701, ⅛-in. female I.P.T. inlet and outlet shall be installed in the fuel line as near the fuel tank as possible on all classes of motor cars.

(c) *Spark Plugs.*—The size of spark plug threads shall be 18 mm., hexagon size ⅞ in. for all classes of motor cars except class MW–F. The thread and hexagon size of spark plug for this class of car is optional.

(d) *Demountable Wheels.*—Demountable plate wheels (16 in. and 20 in.) shall be made to the specifications and within the tolerances shown in Fig. 2710. One-quarter-inch plate wheels shall be used on class MW–B and MW–C cars and 5/16-in. plate wheels shall be used on class MW–D, MW–E and MW–F cars.

Demountable wheels of cast steel, or equal, shall be furnished at the purchasers' option. These wheels shall be designed to interchange with 16-in. and 20-in. demountable plate wheels (Fig. 2710) and shall conform to the general applicable tolerances shown therein.

(e) *Gage.*—The gage on all classes of motor cars furnished for standard track gage shall be 55 11/16 in. as shown in Fig. 2708.

(f) *Headlights and Tail Lights.*—Headlights for all classes of motor cars equipped with battery and generator or no battery generator lighting system, shall be sealed beam type SAE 4012, or equal. Bulb and reflector type headlights may be furnished at purchaser's option. Tail lights shall be SAE 63 or equal.

(g) *Grease Fittings.*—Axle bearings and other parts on all classes of cars equipped for pressure gun lubrication shall be equipped with ⅛-in. pipe thread hydraulic fittings.

(h) *Storage Batteries.*—These shall be furnished at purchaser's option. They shall be six-volt for all classes of motor car. The size and ampere-hour rating are the manufacturer's option.

Storage battery box on class MW–A and MW–B cars shall be made large enough to permit the installation of a battery 9 in. long, 7 in. wide and 9 in. high. The box on other classes of motor cars shall be large enough to permit the installation of a battery 11 in. long, 8 in. wide and 9 in. high.

Standard Parts and Accessories

1. The following motor car parts, accessories or appurtenances shall be applied to all classes of motor cars manufactured and shall be designed to meet the requirements which are listed below:

(a) *Rail Skids.*—The face of the skid which contacts the rail shall be parallel to the side sills of the car and of sufficient width to prevent entrance in a joint gap of ¾ in. When mounted between wheel gage, skids shall have not less than 2¼ in. nor more than 3-in. clearance above top of rail. When mounted directly over the rail the minimum height shall be 1 in. The ends of the skid member which bears on the rail shall be sloped toward the end sills of the car or otherwise protected if necessary to provide safety of operation.

10. Devices for unloading cross ties.

Final report, presented as information .... page 283

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
R. K. JOHNSON, *Chairman.*

Report on Assignment 2

Motor Cars, Trailer and Push Cars

S. E. Tracy (chairman, subcommittee), E. L. Cloutier, C. L. Fero, W. F. Kohl, C. E. Morgan, P. G. Petri, R. S. Sabins, W. I. Stadter, R. D. Timpany, F. E. Yockey.

This is a progress report which includes recommendations for revision of the manual.

Recommendations

It is the recommendation of your committee that the matter on pages 27-1 and 27-3 be deleted and that the following be substituted therefor:

MOTOR CARS

General

1. The capacities, horsepower ratings and weights shown in columns 3 to 6, incl., in Table 1, shall be used as the guide for the classification of all motor cars.

TABLE 1.—CLASSIFICATION OF MOTOR CARS

1	*2*	*3*	*4*	*5*	*6*
Class	*Designation*	*Load Capacity Lb.*	*Rated Seating Capacity Persons*	*Approx. Hp.*	*Maximum Weight Without Accessories Lb.*
MW-A	Light inspection	500	2	4–9	525
MW-B	Standard inspection	750	4	4–9	750
MW-C	Light section	1200	6	4–9	900
MW-D	Standard section	1800	8	8–13	1200
MW-E	Heavy section	1800	8	8–13	1400
MW-F	Heavy duty	Over 1800	Over 8	Over 15	Optional

Materials

Except as noted herein, the materials used for the construction of any class of motor car and for the repair parts and accessories of such a car shall be the manufacturer's option.

Construction

Except as noted herein, the details of construction of any class of motor car and for the repair parts and accessories of such a car shall be the manufacturer's option.

Design

Except as noted herein, the design of any class of motor car and for the repair parts and accessories of such a car shall be the manufacturer's option.

Interchangeability of Parts and Accessories

1. Each manufacturer shall design for the maximum practicable interchangeability of parts and accessories between his several classes of motor cars.

Optional Parts and Accessories

The following motor car parts, accessories or appurtenances shall be applied at the purchaser's option to any class of motor car and shall be designed to meet the requirements listed.

1. Windshields and Cab Tops

(a) Construction details and design shall provide for ready field replacement of parts which become worn or broken in normal use.

(b) Construction details and design shall provide for utilizing the standard safety rails (Figs. 2703 and 2709) and other fixed members of the car and to secure these accessories, whether intended for permanent or temporary application. If the latter type, ease of application and quick removal consistent with safety of operation are of prime importance.

(c) If transparent materials are used in these accessories they shall be of shatter proof (safety) glass, or equal, and of such quality as not to create a distorted view from any angle of vision.

(d) The width of a windshield or a cab top shall not exceed the width of the car upon which it is mounted.

(e) A windshield or cab top that is not as wide as the car shall be mounted with its outer edges equidistant from the center of the deck of car.

(f) A windshield without windows shall not extend more than 28 in. above the seat.

(g) A windshield with windows shall not extend more than 33 in. above the seat.

(h) The height of the inside of a cab top shall not exceed 42 in. directly above the seat at the center of the car.

(i) The top edge of the glass or transparent plastic product shall be not less than 30 in. above the seat. The number of and the size of glass panes are optional but shall provide for satisfactory vision for safe operation of the car.

(j) Windshields and cab tops shall not extend more than 16 in. along the side at the front end of car if such side member is held in a fixed position.

(k) If the fixed side member of a cab top extends 8 in. or more along the side at the front of the car, such side member shall be fitted with a window of sufficient size to permit satisfactory vision.

(l) Any class of motor car equipped with a cab top shall not discharge engine exhaust gasses under the car.

2. Electric Lights

The storage battery type or the no battery generator type shall be furnished at the purchaser's option.

3. Warning Device

The warning device shall be a gong which can be operated either by hand or by foot.

Revision of Drawings

The following corrections in or additions to the Manual are recommended:

Fig. 2701.—Gasoline Line Connections, page 27-2, revise drawing and change title to "AREA Fuel Line and Strainer for Motor Cars."

Fig. 2702.—Couplers For Maintenance Motor Cars, page 27-4, revise and change title to "AREA Coupler Drawhead for Motor Cars, Trailers and Push Cars."

(b) *Extension Lifting Handles.*—Extension lifting handles, front and rear, shall be provided. These may be either the "U" or the straight type. They shall be installed where tools and other materials cannot interfere with free movement and provided with safety stops to hold them at the point of minimum extension and to prevent them from being pulled out beyond the point of maximum extension.

(c) *Wheel Guards and Running Boards.*—They shall be of sufficient width to cover the wheel tread and shall extend the full length of the car.

(d) *Front Axle.*—The front axle except on four-wheel drive cars shall be of the differential type. The differential bearing shall be equipped with a fitting for pressure grease lubrication.

(e) *Brakes.*—Brakes shall be insulated, self-centering and clearing and on all wheels. The design shall provide replaceable liners or facings of cast or malleable iron of sufficient thickness to permit not less than ¼ in. wear before replacement is necessary. Brake liners or facings shall be ground to remove surface chill.

(f) *Paint.*—All motor cars shall be painted as follows: Body, including windshield and cab top, if supplied, the standard yellow for highway signs of the U. S. Public Roads Administration. (See color chart in Chapter 27 of the Manual.) Windshields or cab tops, except those made of canvas, shall be given a primer coat and two coats of paint.

Wheels and safety rails—black
Fuel tank—red.
All other parts—manufacturer's option.

(g) *Frame Bolts.*—Frame bolts in wood frames shall have National coarse cut threads and be equipped with head locks and lock nuts. Frame bolts in metal frames shall have National fine threads and shall be equipped with lock washers.

(h) *Safety Rails.*—Safety rails, tool guards and tool trays for class MW–C, MW–D, MW–E and MW–F cars shall be made per Fig. 2703. Safety rails, tool guards and tool trays for class MW–A and MW–B cars shall be made per Fig. 2709.

(i) *Coupler Drawhead.*—A coupler drawhead of the type or equal shown in Fig. 2702 shall be applied to the rear of all classes of motor cars except classes MW–A and MW–B. A coupler drawhead on these classes and on the front end of all classes of motor cars shall be applied at the purchaser's option. The method of attaching it to the motor car shall provide for pushing and holding back the load as well as for pulling it.

(j) *Belts.*—Belts of the endless cord type shall be supplied.

(k) *Fuel Tanks.*—Fuel tanks shall be made of not less than 22 B.W. gage (0.028 in.) terne plate, cylindrical or oval in shape with convex or concave ends; seam locked and soldered or welded. Filler openings shall be 1⅝ in. inside diameter and equipped with bayonet type cap having a gasket and an inner splash cone, 1/16-in. vents in the cap and the splash cone. The fuel outlet fitting shall be a female ⅛-in. I.P.T. The fuel tank shall be mounted as far away from the engine and exhaust discharge as the design will permit.

(l) *Rail Sweeps.*—Rail sweeps shall be applied at the purchaser's option. Positive stops shall be provided to prevent the metal parts from contacting wheel flanges and the flexible nonmetallic parts from contacting wheel treads.

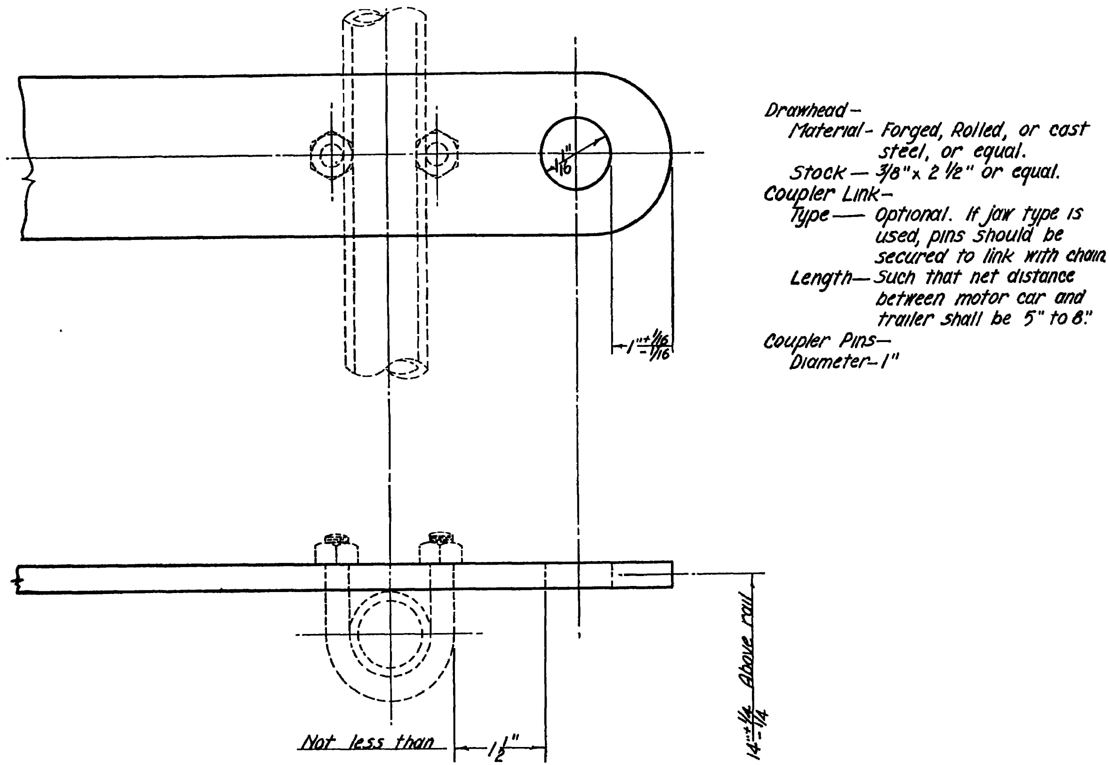

Fig. 2702.—AREA Coupler Drawhead for Motor Cars, Trailers and Push Cars.

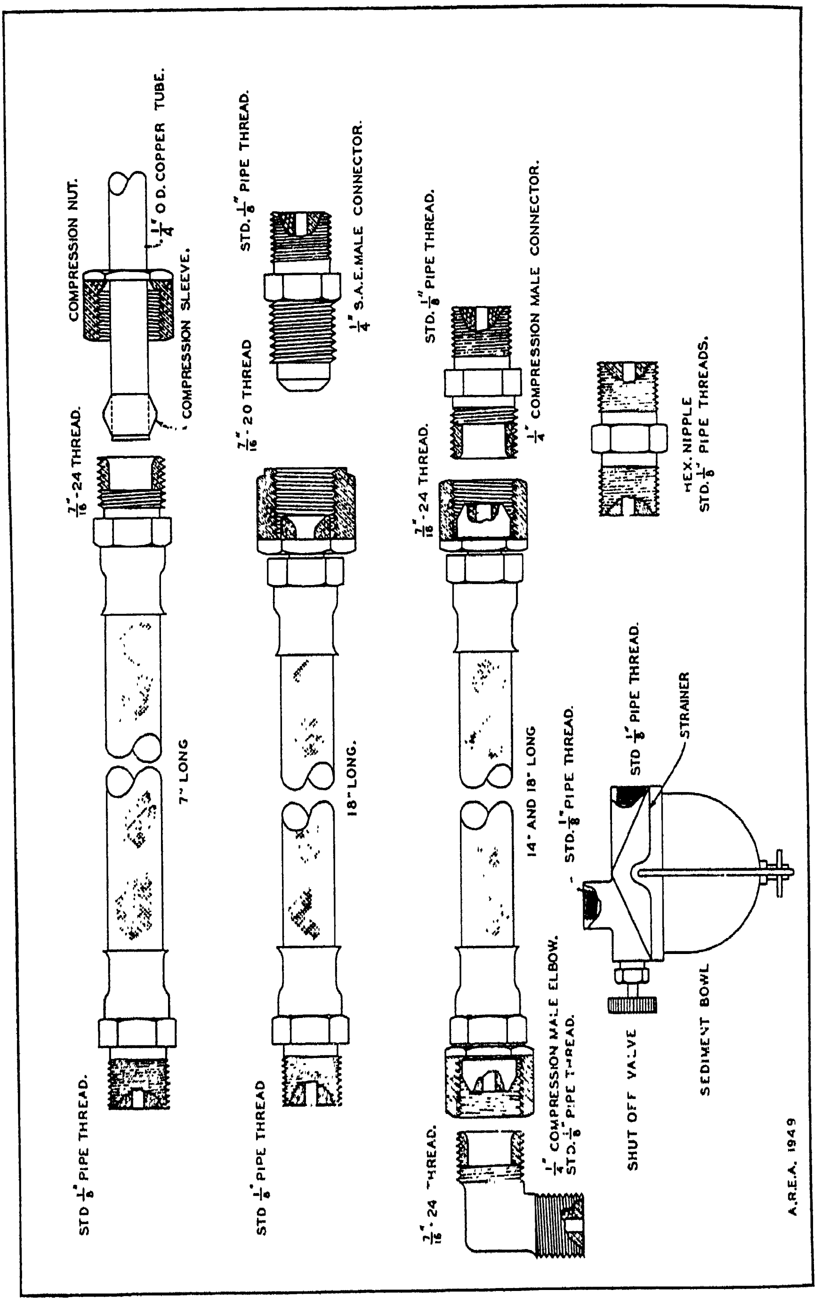

Fig. 2701.—AREA Fuel Line and Strainer for Motor Cars.

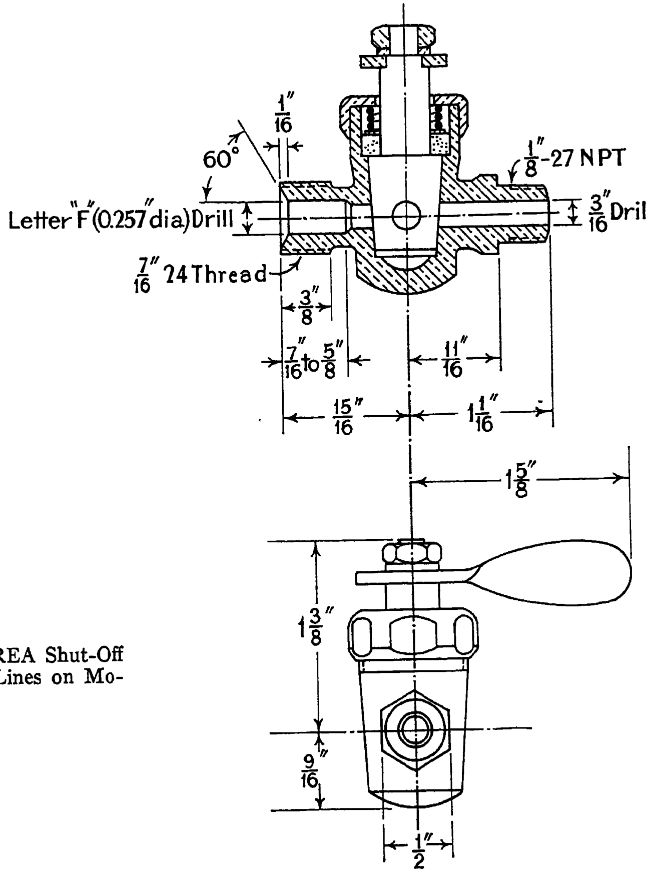

Fig. 2707.—AREA Shut-Off Cock For Fuel Lines on Motor Cars.

Fig. 2703.—Safety Rails For Maintenance Motor Cars, page 27–5, revise and change title to "AREA Safety Rails, Tool Guards and Tool Trays For Class MW–C, MW–D, MW–E and MW–F Motor Cars."

Fig. 2704.—AREA 1½-in. Axle and Ring Gage For Checking Dimensions for Maintenance Motor Car Axles, page 27–6, change title to "AREA 1 7/16-in. Axle and Ring Gage for Motor Car, Trailer and Push Car Axles."

Fig. 2705.—AREA Wheel Tread and Flange For 16-in. and 20-in. Wheels on Motor Cars, page 27–6.1, delete the word "Maintenance" and add "Trailers and Push Cars" after "Motor Cars" in present title.

Fig. 2706.—AREA Typical Designs For Grease Cups For Use On Maintenance Motor Cars, page 27–6.2, delete from the Manual.

Fig. 2707.—AREA Preferred Type of Shut-off Cock For Gasoline Lines on Maintenance Motor Cars, page 27–6.3, change title to "AREA Shut-off Cock For Fuel Lines on Motor Cars." Revise drawing to show ⅛-in. I.P.T. on one end and 7/16 by 24 thread male compression fitting for flexible fuel line on the other end.

Fig. 2708.—Gage For Mounting Wheels on Maintenance Motor Cars, page 27–6.4, delete the word "Maintenance" in the title and add "Trailers and Push Cars" after "Motor Cars."

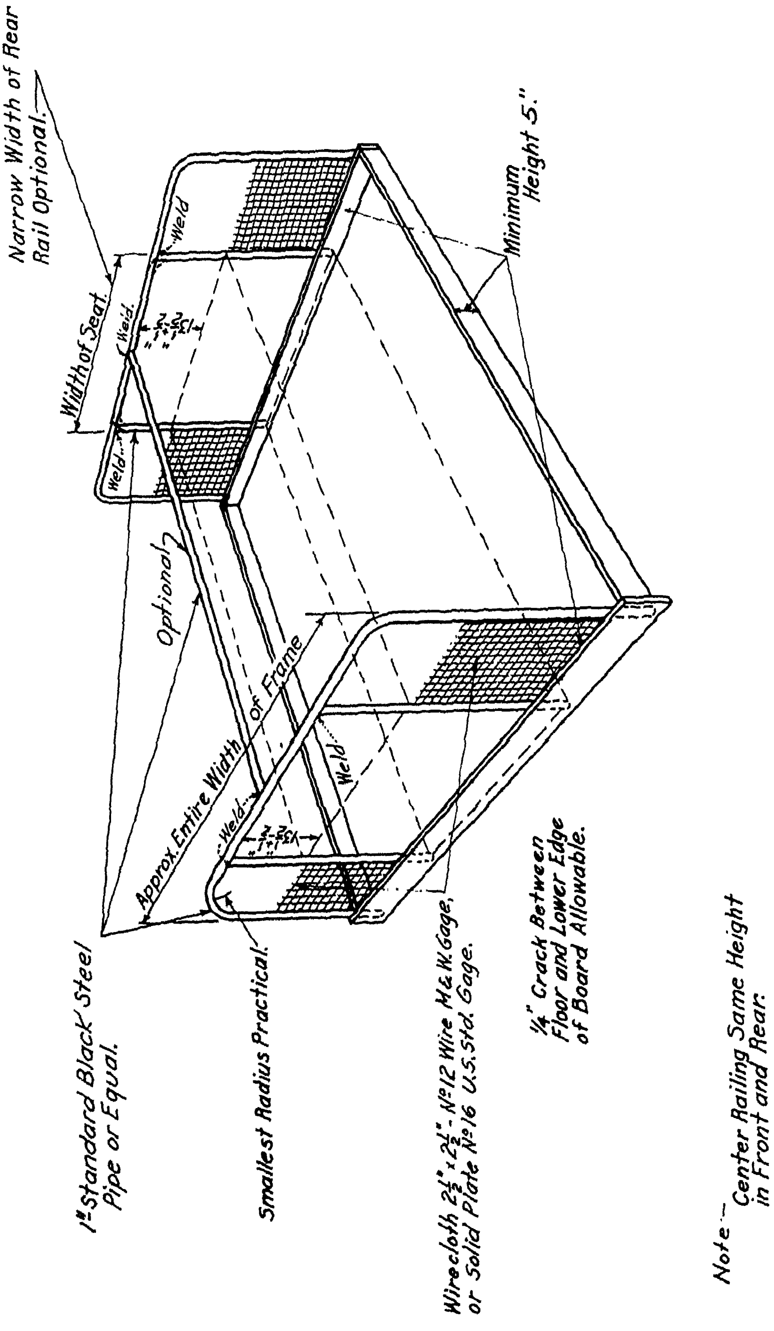

Fig. 2703.—AREA Safety Rails, Tool Guards and Tool Trays for Class MW-C, MW-D, MW-E and MW-F Motor Cars.

Fig. 1.—Spray Cars Designed for Movement in Trains.

First, there are the spray cars designed for movement in trains, which usually consist of a flat or box car upon which is mounted spray headers, control valves, meters, strainers, nozzles, pumps, etc. Directly behind, and attached to, the spray car are one or two mixing tanks of 8000 to 10,000 gal. capacity, and supply cars. See Fig. 1.

Small on-track spray machines, with a tank capacity ranging up to 2500 gal., self-propelled or towed by a motor car, are also used for the control of vegetation. Up to the present time, the majority of spray outfits of this type have been constructed by the various railroads according to their own ideas. One manufacturer of railroad equipment has recently developed a small machine of this type. See Figs. 2 and 3.

For work in relatively inaccessible areas, a crawler tractor and one or two crawler trailers are customarily used. A pump is mounted on the tractor and is run from a power take-off. The spray solution is carried in a tank on a trailer. A high-pressure hose is generally provided in 50-ft. lengths and it is practicable to attach up to four sections to allow a working radius of 200 ft. from the equipment. Depending on the capacity of the pump, several lines of hose may be used, each being controlled by a spray man. The hose can be connected to one nozzle, or a short length of pipe containing several nozzles, depending upon the type of spray work being undertaken and the conditions encountered.

Small wheelbarrow and "pack back" types, with capacities ranging from 5 to 50 gal., are used for spot work around buildings, under trestles, and other places inaccessible to larger equipment.

For killing vegetation beyond the limits of the ballast section, the right-of-way can be sprayed by both off-track and on-track equipment. On-track spray cars, designed for movements in trains, equipped with retractable extension spray arms, which can spray out to approximately 30 ft. from the center line of track, are now in use on some railroads and work very satisfactorily. See Figs. 4, 5, and 6. Beyond this point, it is necessary to use off-track equipment. Where the terrain permits, automotive type spray equipment of various types may be used. Off-track equipment, for application of weed killers, do not fit any general pattern. Various types of special equipment have been designed to fit particular working conditions. In general, however, trucks are used whenever possible. Ordinarily, pumps with a 1½-in. intake and discharge line, and capable of developing up to an 80-psi. pressure, are used. Trucks also carry solution tanks with a 400 to 1000-gal. capacity.

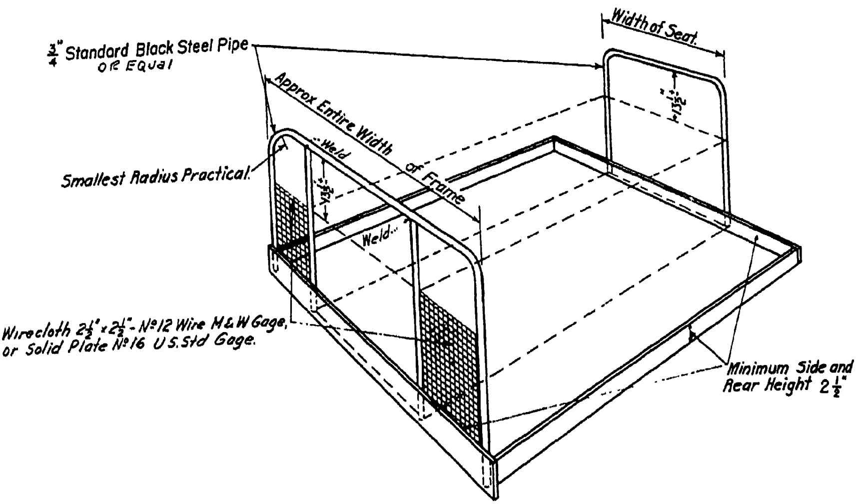

Fig. 2709.—AREA Safety Rails, Tool Guards and Tool Trays for Class MW-A and MW-B Motor Cars.

Fig. 2709.—Safety Rails for Light Inspection Motor Car, page 27-7, revise and change title to "AREA Safety Rails, Tool Guards and Tool Trays for Class MW-A and MW-B Motor Cars."

Fig. 2710.—AREA 16-in. and 20-in. Bolted Demountable Plate Wheel Using ⅛-in. Insulating Bushing For Motor Cars with 1-7/16-in. Axles, page 27-8, add "Trailers and Push Cars" after "Motor Cars" in the title.

Report on Assignment 3

Spray Equipment to Control Vegetation on Track and Right-of-Way

M. C. Taylor (chairman, subcommittee), R. M. Baldock, C. T. Blume, W. M. Dunn, F. L. Etchison, E. C. Jackson, Jack Largent, J. R. Rushmer, J. L. Starkie.

This is a progress report presented as information.

Previous reports on, or relative to, weed killing, appeared in AREA Proceedings as follows:

Weed Killing—Committee 1, Vol. 31, 1930, pages 615-624, incl.

Use of Weed Destroying Equipment, Etc.—Committee 27, Vol. 35, 1934, pages 498-505, incl.

Economics of Methods of Weed Killing—Committee 22, Vol. 37, 1936, pages 236-250, incl.

Weed Burners and Extinguisher Cars—Committee 27, Vol. 44, 1943, page 263.

Spray equipment to control vegetation has been in use on railroads for many years, but in the past, has been generally confined to the ballast section of the roadbed. The types now in general use are divided into several classes, as follows:

Fig. 4.—Sprayer with Retractable Extension Spray Arms, Spraying in Yards.

Fig. 5.—Sprayer with Retractable Extension Spray Arms, Spraying Right-of-Way.

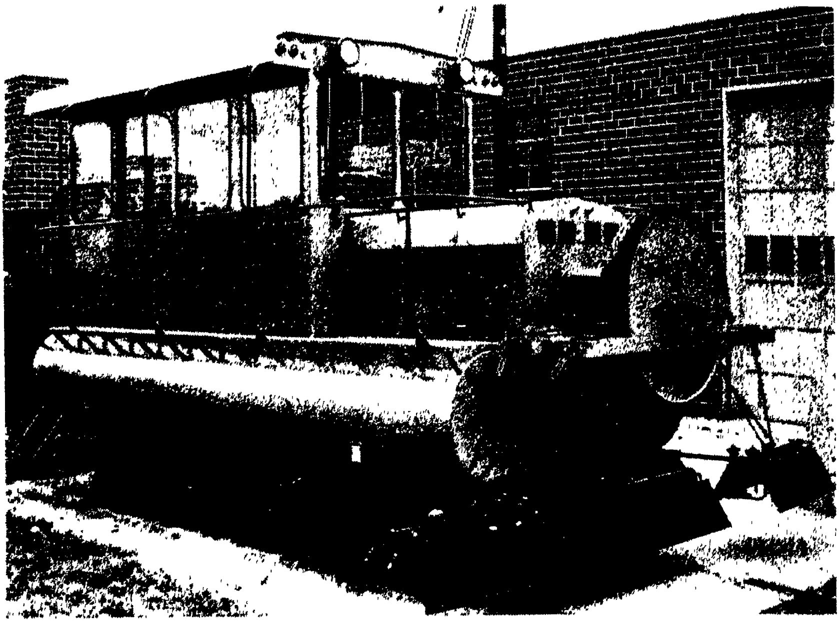

Fig. 2.—Small, On-Track, Self-Propelled Sprayer.

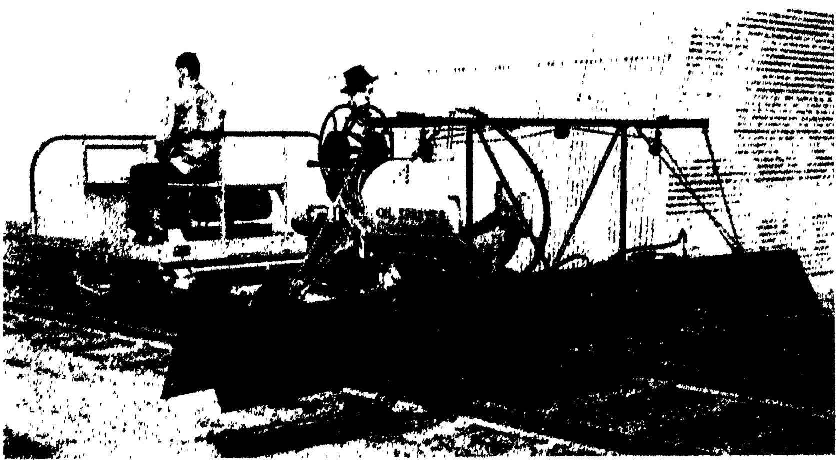

Fig. 3.—Small, On-Track Sprayer, Towed by a Motor Car.

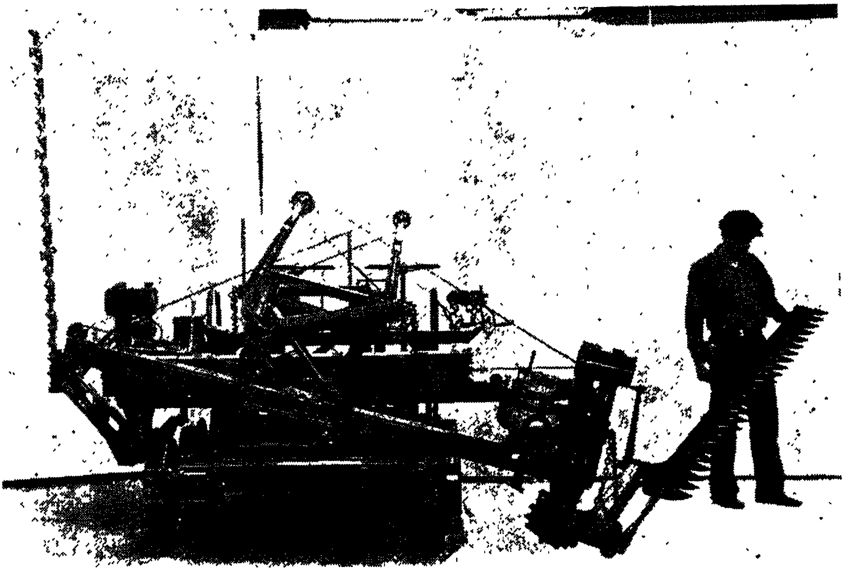

Fig. 1.—On-Track Type Mower.

Fig. 2.—Off-Track Type Mower.

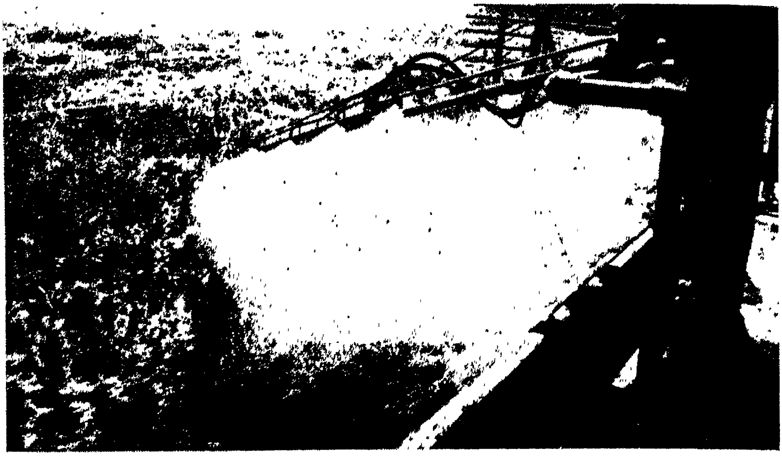

Fig. 6.—Sprayer with Retractable Extension Spray Arms, Spraying Right-of-Way on Fill.

The spray unit, whether on a truck or tractor and trailer, is usually served by a mother-truck unit. The spray solution is prepared in the mother-truck tank, hauled as near as possible to the point of operation of the spray unit and transferred to the spray unit tank. The mother-truck has long lengths of hose to facilitate transferring the solution when the two units cannot be brought close together. While the spray unit is operating, the mother-truck moves to the nearest supply source for preparing a new batch of solution. This enables the spray unit to continue work with the least delay. If spray materials are not immediately available, it is practical to use two or more mother-trucks to keep the spray unit supplied.

Report on Assignment 4

Power Mowing Machines and Desirable Attachments

L. E. Conner (chairman, subcommittee). E. L. Anderson, R. E. Berggren, C. T. Blume, Jack Largent, F. H. McKenney, M. M. Stansbury, J. L. Starkie, E. G. Wall.

This is a final report, submitted as information.

The subject is closely related to, and can be considered as a continuation of the report "Mowing Machines," recorded in the AREA Proceedings, Vol. 45, 1944, pages 102–108, incl. However, this previous report covered only mowing machines without attachments.

Mowing machines are constructed in a wide variety of types, but the general basic principle of operation is that of a reciprocating sickle, operated through guards on a cutter bar by belts, gears or hydraulic motor, all of which derive their power from an internal combustion engine. Some of these machines are track-mounted; some are of the off-track type, mounted on four rubber or steel tired wheels; others have one or two wheels which support the engine, the machine being propelled by power but controlled by an operator on foot.

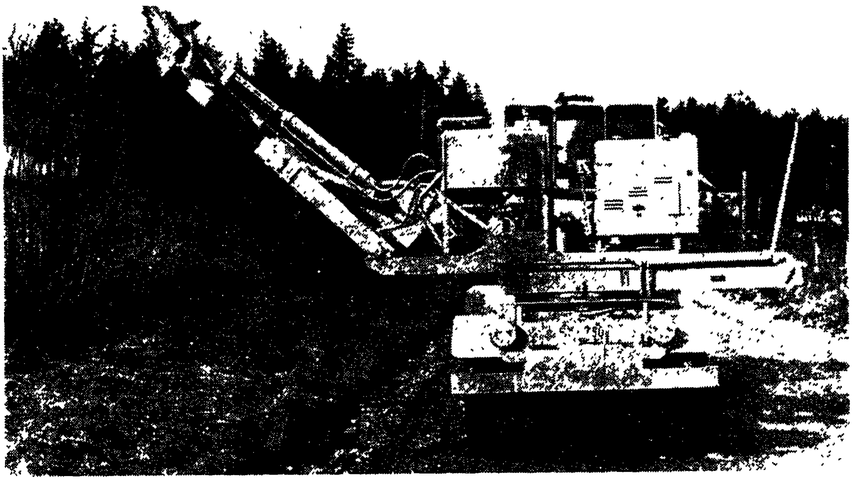

Fig. 5.—Heavy-Duty Truck-Mounted Mower; Cutter Bar in Retracted Position.

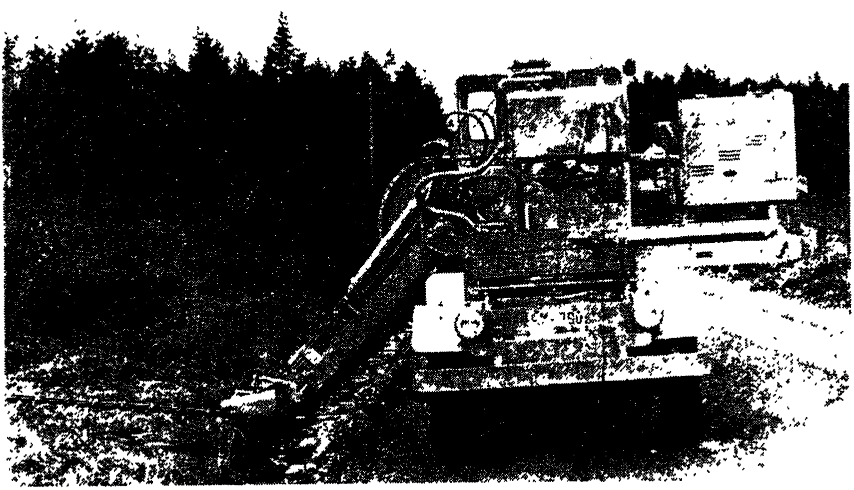

Fig. 6.—Heavy-Duty, Truck Mounted Mower; in Fully Extended Operating Position.

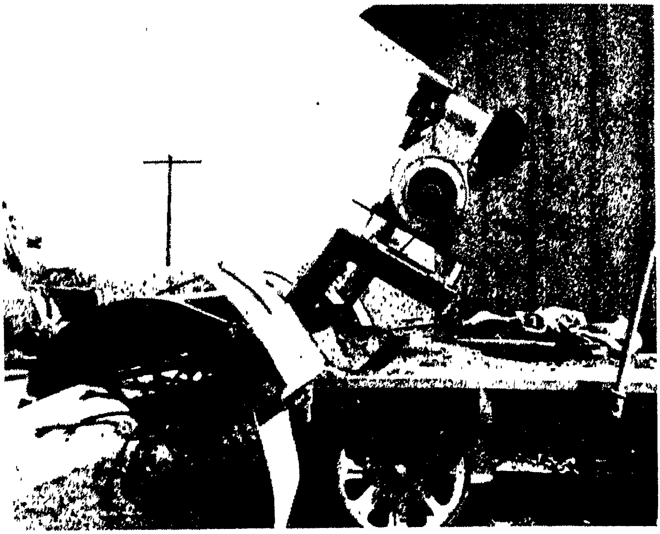

Fig. 3.—Weed Whipper.

Fig. 4.—Weed Eradicator and Ballast Brush.

Report on Assignment 5

Devices for Loading and Unloading Roadway Equipment

R. E. Berggren (chairman, subcommittee), W. R. Bjorklund, C. L. Fero, E. C. Jackson, W. B. Lee, Francis Martin, C. E. Stoecker, R. D. Timpany, F. E. Yockey, F. F. Zavatkay.

This is a final report presented as information.

Small machines, such as track wrenches, spike pullers, adzers, creosoters, spike drivers and rail drills, when used in rail laying operations, are usually handled with the rail crane; however, at least one railroad has specially equipped flat cars for carrying this equipment. These cars, which have rails attached to the deck, also have rails bent and fitted for use as a ramp over which the equipment is pushed by the crane or propelled under its own power for loading or unloading. Jib cranes are also used by some railroads to load equipment on to flat cars or into tool cars. In these cases the crane is mounted on the flat car or at the door of a tool car.

The rail type ramp supported by steel posts, ties or wood timbers affords the usual means also to load rail cranes. Steel supports have been developed for use under the ramp rails. These supports, made up of tubing or of steel beam sections, channels, angles and steel plates, are of several lengths to suit the angle of the ramp, the heaviest of which weighs less than 75 lb. When properly tied together they make a satisfactory support for a rail ramp.

A rail crane manufacturer offers a portable rail loading ramp in which rails are stiffened by attaching an 8-in. I-beam to the rail base. Cross members tie the rails together permanently in one piece. Lifting rings are properly located for balanced lifting with the crane. This rail assembly is then held up by two steel supports placed between the ramp and the track rails. In all cases the ramp rails are bent at the upper end to fit the carrier car floor and joint bars connect the ramp rails to the rails, which are permanently attached to the car.

Crawler cranes and draglines usually have regular carrier cars assigned to them. Many railroads have the cars equipped with a ramp consisting of heavy I-beams 18 in. to 24 in. These members have suitable steel supports welded to the web on the under side which rest on the rail. The upper end of each I-beam has a two-pin hinge permitting the complete ramp to be raised and swing back to rest on the car. Fig. 1 shows the process of unloading a crane. A wood liner is bolted to the car floor and to the ramp to prevent slipping of the tracks. Where this equipment is not available, another method of loading crawler cranes and draglines may be employed, which involves the jacking up of the light end of the car, removal of one truck and lowering the car body to rest on the rails. One railroad reports a complete one-piece wooden ramp used with a crane or shovel. Figs. 2 and 3 show method of use. The ramp is carried on the car with the machine.

Heavy tractors, because of lack of lifting facilities, are usually loaded by means of a ramp composed of heavy timbers supported on wood blocking.

One manufacturer of crawler cranes offers an on-track trailer with a short loading ramp for carrying crawler cranes. A power take-off arrangement is povided whereby the trailer is propelled by the crane engine while the crane is in place on the trailer.

Track-mounted welding equipment, grinders and push cars forming one unit, are provided on one railroad with a carrier car equipped with permanently mounted rails

It is not deemed advisable in this report to confine attention to any one particular type of power mower or attachment.

The on-track type mower is used mostly on branch lines, some secondary lines, industrial tracks, yards and terminals; however, these machines leave a narrow strip of growth at the head of ties or ballast toe line. (See Fig. 1.)

Many railroads are resorting to the off-track mower in controlling vegetation on the right-of-way. The four-wheel tractor type mower is very popular in this work; however, in many locations, because of the terrain, tractor mowers cannot be used. As a matter of fact, hand labor is used in some locations where no type of mechanical mower can be used. It nevertheless has been found by many that off-track mowers of this type have more than proved their worth. (See Fig. 2.)

A number of attachments are available for the four-wheel, rubber-tired, tractor type mowers, as follows:

(a) Front-end loaders.
(b) Manure loaders and scrapers for stock pen use.
(c) Terracing blades for landscaping.
(d) Bog discs for grassing under trestles and bridges.
(e) Plows for fire breaks and landscaping.
(f) Rear mounted scraper pans for moving dirt, cleaning ditches, and removing bark from pulpwood loading tracks and sidings.
(g) Plow blades.
(h) Snow blades.
(i) Rotary brooms.
(j) Post hole diggers.
(k) Rakes for cleaning debris.
(l) Weed spray attachments.

Another type of the off-track mower, but on a smaller scale, is the two wheel sickle-bar mower, powered by a small gasoline engine. This type of mower plays a big part around station grounds and out on line where the larger four-wheel tractor type cannot maneuver. Bull-blade attachments are also available for these mowers for use in sections of the country where snow is experienced.

There has been developed by one railroad a weed whipper for the control of vegetation, as shown in Fig. 3, which consists of a horizontal shaft mounted on the end of a standard push car in a manner that permits raising and lowering. This shaft is driven by a gasoline engine through a V-belt drive. Secured to this shaft at right angles, is a series of short steel cables which are wrapped a short distance from the end, permitting the ends to fray and cover a greater area. This shaft, revolving at a high speed, produces a severe whipping action, which cuts any vegetation the cables contact.

One manufacturer recently has developed a machine similar to the weed whipper, known as a weed eradicator and ballast brush, which is towed by a motor car. (See Fig. 4.)

Of recent development also is a heavy duty truck-mounted, hydraulically controlled and hydraulically actuated mowing machine, shown in Figs. 4, 5, and 6, capable of cutting woody plants up to a maximum diameter of 3½ in. This machine has a vertical height of 19 ft. and a maximum horizontal length of 18 ft. from front wheels of chassis. This machine is also available in a type suitable for mounting on railway equipment.

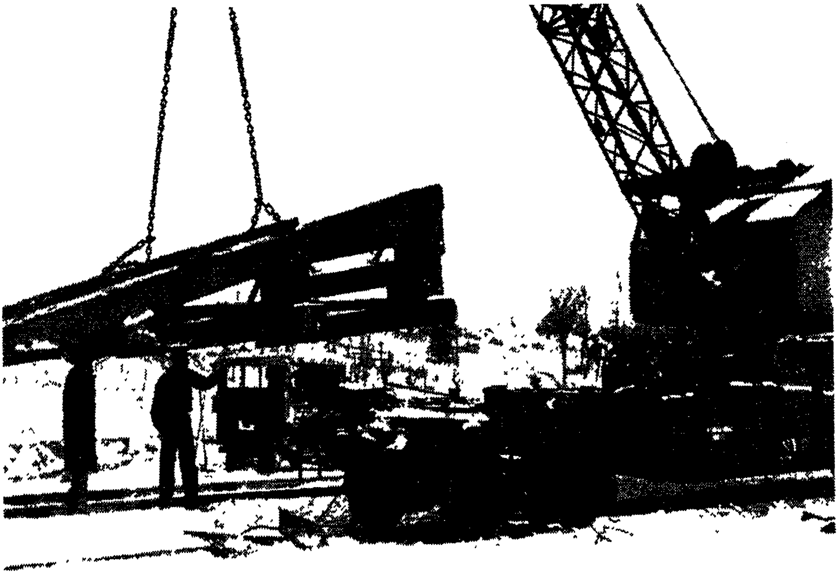

Fig. 2.—Setting Wooden Ramp in Position for Use.

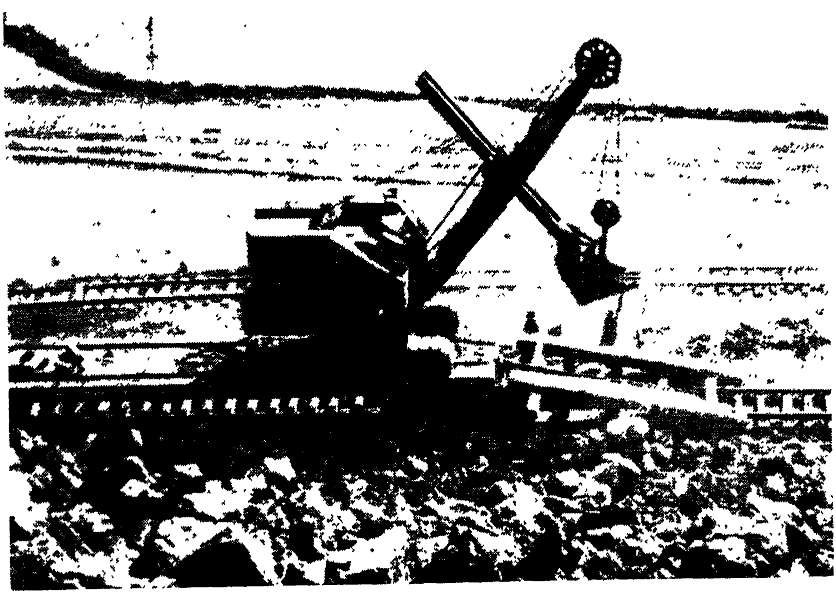

Fig. 3.—Power Shovel Placing Ramp in Position.

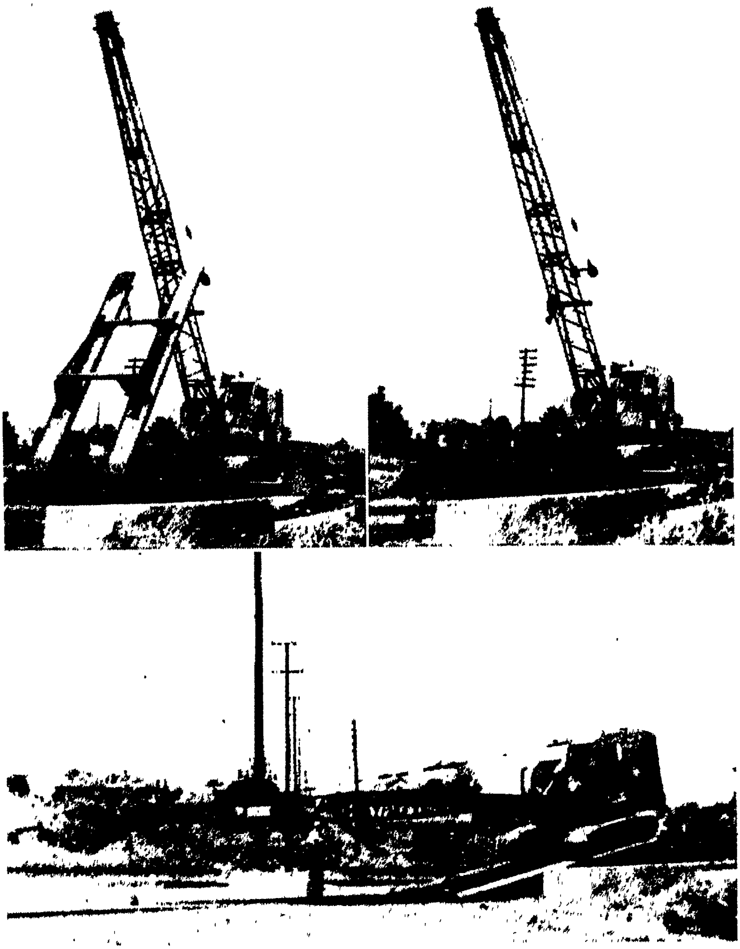

Fig. 1.—Upper Right, Crane and Ramp on Car; Upper Left, Ramp Being Unloaded; Below, Crane Moves Down Ramp.

on the deck. Detachable ramp rails are also used and connected to brackets on the car. Loading is accomplished by the use of heavy block and falls, or a hand winch attached to the car.

When highway trailers are used for transporting equipment the loading and unloading is simplified in that the trailers are low and already equipped with short sturdy ramps which fold back or are easily removed. Smaller highway trailers have tilting tops which serve as the ramp.

15. Sudden starts and stops, and rapid turning of corners should be avoided.
16. The following practices are prohibited:

(a) Allowing more than two other persons to occupy the driver's seat.

(b) Boarding or leaving a vehicle except by using steps where steps are provided.

(c) Boarding or leaving a vehicle while it is in motion.

(d) Sitting in such a manner that a foot or arm extends over the sides or ends of a vehicle, while it is moving.

(e) Riding on material that is likely to shift, or in that part of a truck where a shifting load may cause injury.

(f) Standing while riding in a truck.

(g) Throwing material or tools from a moving vehicle, except as required and authorized.

(h) Permitting an engine to run in a closed or unventilated garage or building, or when the gasoline tank is being filled.

(i) Smoking, or using an open flame, while a gasoline tank is being filled or while gasoline or other flammable liquid is being handled.

(j) Speeding or reckless driving.

(k) The use of unauthorized devices on vehicles.

(l) Coasting down hills, except as necessary in an emergency.

17. All vehicles must be equipped with an approved fire extinguisher which must be kept in good operating condition, and the driver must know how to operate it.

18. All vehicles shall be equipped with first-aid kits. These shall be kept properly stocked and carried in the cab; preferably in the glove compartment.

19. If a vehicle should catch fire while in motion, it shall be stopped, the occupants vacated in an orderly manner, and the fire extinguisher used. If the fire is of such a nature that it cannot be readily extinguished with the hand extinguisher, a fire department should be called, if one is available. Every effort must be made to prevent panic and to keep the occupants from jumping from the vehicle before it has come to a complete stop.

20. Employees shall not get under a vehicle when two or more wheels are off the ground or floor, unless the vehicle is properly blocked in a safe position, and the engine is stopped.

Accidents

21. In case of accidents involving company-owned vehicles, resulting in personal injuries or damage to property, the operator shall:

A. Take care of injured persons.

B. Obtain full names and addresses of all persons who witnessed the accident or have any direct knowledge of it.

C. Obtain names and addresses of driver of other vehicle or persons therein, and of any persons injured.

D. Obtain the license number and vehicle registration number of the other vehicle.

E. Report the accident to state or local authorities, as required.

F. Report to the supervisory officer, giving in addition to above:

(a) Nature and seriousness of injuries to persons, or damage to property.

(b) Time and location of accident.

Report on Assignment 6

Instructions for the Care and Operation of Company Owned Automotive Equipment

N. W. Hutchison (chairman, subcommittee), W. S. Brown, E. L. Cloutier, L. E. Conner, A. J. Flanagan, Bernard Geier, Francis Martin, V. W. Oswalt, Sr., M. M. Stansbury, C. E. Stoecker, A. H. Whisler.

This is a final report submitted as information.

General

1. These instructions apply to all company owned trucks, buses, and passenger automobiles herein referred to as vehicles.

2. The term "operator" refers to that person who normally drives a vehicle.

3. The operator of a vehicle must be qualified, have a driver's license and any other required credentials and must know and obey all of the driving laws and regulations of the state, city, and county in which the vehicle is operated. Driver's license, registration card and any other credentials must be in the vehicle, or with the driver, as required.

4. Company owned vehicles shall not be used for any purpose other than company business, and shall not be operated at any time off company property except where the required license tags are properly displayed.

5. Only employees in the discharge of their duties shall be permitted to ride in a truck or bus, unless special permission is obtained from a supervisory officer of the department. The operator, while driving, must not engage in needless conversation with other riders, nor they with him.

6. Automobiles, trucks, and buses shall be kept in a clean and presentable condition. The foreman, operator, or other person to whom a vehicle is normally assigned shall be directly responsible for its proper maintenance and appearance.

7. Trucks shall not be overloaded, nor shall the load exceed the maximum length, height, and width permissible under state or other regulations.

8. Automobiles, trucks, and buses shall be housed in a garage whenever possible.

Safety

9. Safety is of first importance in the discharge of duty.

10. Obedience to these instructions is essential for safety.

11. In case of doubt or uncertainty, the safe course must be taken.

12. The foreman, operator, or other person in charge, is responsible for the safety of the occupants of a vehicle and must see that the men do not enter or leave it while it is in motion. He must be at the rear of a truck or door of a bus to supervise the loading and unloading of men. He shall give necessary signals and see that everything is in order before a move is made. Where the foreman, or other person in charge, is also the operator, he shall authorize a qualified employee riding in the back of the truck to give the signals.

13. When necessary, material hauled in a truck should be properly blocked to prevent shifting.

14. On trucks equipped with a signal device between the rear of the truck and the driver's seat, the signals to be used are as follows:

Stop—One ring
Start—Two rings

36. Under no circumstances shall a vehicle be operated at speeds in excess of those prescribed by state laws or local ordinances and trucks rated at 1½ tons or more shall not be operated at a speed of more than 35 mph.

37. Regardless of speed laws, any vehicle must be operated slowly and carefully past a school, where children are playing, where traffic is heavy, where visibility is limited, or under any other conditions where slow speed is a necessity for safety.

38. Speed at night shall be consistent with the brilliance of the headlights and the ability of the operator to see the road ahead.

39. The operator will be responsible for any fines or time lost when arrested and found guilty of speeding or reckless driving.

40. Speeding, reckless driving, or misuse of a vehicle will be sufficient cause for disqualifying an employee from driving a company vehicle.

Adverse Weather Conditions

41. When weather conditions are bad, the operator must drive in such manner and at such speed as to insure that he has complete control of the vehicle, particularly on curves, hills, intersections, junctions, and railroad crossings.

42. Extra caution must be exercised in operating a vehicle on icy roads or streets. When necessary for safe operation, tire chains must be applied. Spinning of the wheels and sudden application of brakes should be avoided.

43. When necessary to pass through water deep enough to flow into the brake drums, the brakes should be lightly applied several times while passing through the water and again after clearing the water, to prevent foreign matter from collecting on the surface of the brake linings.

Warning Signals

44. The horn must be sounded before passing vehicles that are moving in the same general direction, when approaching intersections where the view is obstructed, when approaching persons in close proximity to the point where the vehicle will pass, and under such other conditions as are necessary to insure safety. Unnecessary use of the horn is prohibited.

45. When making a turn, either from a standstill or while in motion, a signal must be given, either by hand or by directional lights, to indicate the direction of turn.

46. When pulling away from a curb, not only should a signal be given, but the operator should look back to make sure that no other vehicle is approaching to his immediate rear.

Railroad and Street Railway Crossings

47. Before crossing the tracks of any railroad or interurban railway at grade, the operator of any vehicle shall come to a full stop, look, and listen and then proceed, when the track is clear. Unless a vehicle is stenciled "This Vehicle Stops at all Railroad Crossings," the operator must give ample warning to following motorists that he is going to stop. Where the view is obstructed and there are other employees in the truck, one of them shall be directed to get out of the truck, look up and down the track and give a proceed signal. When crossing, the vehicle should be in low gear, and gears should not be shifted during the crossing.

48. Before crossing any street railway, except where there is a watchman, traffic officer, or signal light, the speed shall be reduced to 15 mph., and the crossing made cautiously.

(c) Condition of weather and roads.

(d) Description and direction of vehicles involved.

22. If a vehicle strikes any object on, or near, the highway, particularly at night, the operator must stop and investigate. If a pedestrian is struck, the operator must not leave the scene of the accident, except to take care of an injured person or to summon aid. Such an accident must be reported to the proper authorities promptly and fully.

Operation

General

23. An operator shall acquaint himself with the mechanical and electrical details of the vehicle he operates, in order that he may make minor repairs.

24. The operator of a vehicle should become familiar with the sound made by it when it is operating correctly. Any knocking or other unusual noise must be investigated promptly and the cause corrected.

25. Ordinary driving courtesies, warning signals, etc., must be observed.

26. Government mail trucks, police cars, fire trucks, military cars, ambulances, and funeral processions, must be given the right-of-way on any street or highway.

27. A truck or bus must not so occupy any thoroughfare as to obstruct traffic or constitute a menace to other drivers.

28. If a company vehicle is to be driven on private property, permission must first be obtained from the owner. Care shall be taken to close all gates which may have been opened for passage of the vehicle.

29. If and when a truck or bus breaks down on the road, flags or flares shall be placed in position and the vehicle removed from the traveled portion of the road as promptly as possible.

30. The three main essentials for operating any vehicle are, in order of importance: Oil, water, and fuel. Running out of fuel results only in a short delay; running out of oil or water results in long delays and generally expensive repairs. It is vitally important that a close check be kept on the lubrication and cooling system; not only to see that there is an adequate supply of oil and water but that these systems are functioning correctly.

31. New or overhauled engines should always be "broken in" gradually. They will give better performance and longer life if they are not worked too hard during the "breaking in" stage.

32. A vehicle must not be operated on a flat tire, except in an emergency.

Testing

33. At the beginning of each day of operation the operator must check the brakes, horn, windshield wiper, headlights, taillight, and defroster (in winter), to see that they are all in good operating condition. He shall also check the crankcase oil level, radiator water level, and tire pressures, and assure himself that his flagging equipment and flares are in the vehicle.

34. Before, or after starting a trip, and frequently during the operation of the vehicle, the battery charging, temperature, fuel, and oil pressure gages shall be observed. Any abnormal indication in these gages should be immediately investigated.

Speed

35. Vehicles at all times shall be driven at a safe and reasonable speed, giving due regard to traffic and other local conditions, the use of the highway and safety of the public.

Clearances

62. A truck or bus operator must be familiar with the height and width of the vehicle he is operating and the load he is hauling, and the clearance restrictions of the state, city, or county in which the vehicle is operated, and must know that the truck and the load are within the clearance restrictions.

63. Operators shall exercise care in passing under low structures; such as, bridges, wires, tree branches, etc. Particular care in this respect should be given when operating over country roads and portions of the railroad right-of-way.

64. In approaching street curbs, care must be taken to see that overhanging portions of a truck do not strike pedestrians on the sidewalk, other vehicles, lamp posts, telephone poles, and any other obstructions near the curb lines. Particular care must be exercised when necessary to drive close to open excavations.

65. No vehicle shall be driven across a bridge on which the load limit is less than the weight of the vehicle and its contents.

66. Loads that overhang the rear end of a truck, and constitute a menace to other vehicles, shall have attached to the rear end of the load a red flag or rag by day; a red lantern by night.

Disabled Vehicles

67. When any vehicle, while in service, becomes disabled, the operator shall promptly notify his supervisory officer, giving complete information as to the nature of the defect and whether or not it is possible to drive the vehicle to headquarters. If the defect is of such a nature as to make its operation unsafe, the vehicle shall not be moved.

68. Under no circumstances shall the operator of a vehicle have any repair work performed on it by outside parties except when specifically authorized by his superior officer.

Maintenance

General

69. When any maintenance work is required on a vehicle which the operator is unable to perform, he shall advise his supervisory officer and be governed by instructions received.

70. At the close of each day of operation, a check shall be made to see that there is plenty of fuel. The fuel tank on any vehicle should, at the close of the day, be full, if at all possible, in order that it may be immediately ready for emergency use at night, and to minimize condensation in the fuel tank and resulting contamination of the fuel with water.

71. The operator of a vehicle shall be held personally responsible for repair tools furnished with the vehicle.

Lubrication

72. Any vehicle shall be lubricated in accordance with the recommendations contained in the maintenance instruction book issued by the manufacturer for the particular vehicle involved.

73. To be effective as a lubricant and as a cooling agent, oil must circulate freely. Oil lines, oil pump screen, and oil filters must be kept clean. Where the oil filter is equipped with a renewable filtering element or cartridge, this should be renewed in accordance with the manufacturer's recommendations.

74. When starting an engine, it should be idled slowly, until the oil is flowing freely, before the vehicle is started. This is particularly important in cold weather. Racing of a cold engine is prohibited. Unnecessary idling should be avoided.

Handling Vehicles on Hills

49. A vehicle operator should remember that passing over the brow of a hill is just as dangerous as passing around a curve on the level and that similar precautions are necessary. Speed should be reduced when approaching the top of a hill in order that the vehicle may be brought to a complete stop if necessary.

50. Even though a steep hill may be climbed in high gear, it is usually better to shift into second gear and this should be done when it seems necessary. This will minimize strain on the engine and the hazard of stalling.

51. When approaching the top of a hill, the vehicle should be kept on the right side of the road.

52. A vehicle should not be held on a hill by "slipping" the clutch, nor should the clutch be "slipped" unnecessarily under any condition.

53. On very steep hills, before starting the descent, the operator of a truck or bus shall shift into lowest gear, thus using the engine compression as a brake, in addition to the foot brake. Where the steepness of the hill does not require using the lowest gear, a higher gear may be used. It is advisable to use the same gear that would be used in climbing the same hill. If necessary to apply the foot brake continuously to keep the speed of the vehicle under control, it is an indication that it should be in a lower gear.

54. In descending a hill in high gear, the braking should be done by periodic applications of the brake, or "snubbing." Continuous application of the brakes will cause them to heat excessively and will damage the drums and lining.

Handling Vehicles on Curves

55. When approaching a curve, the speed of the vehicle should be reduced, particularly on a down grade. In rounding a curve at reduced speed, the vehicle can be kept on its own side of the road, thus avoiding collision with any vehicle coming from the opposite direction. The major part of the braking should be done before the curve is reached.

56. In rounding a curve, the vehicle must be kept on the right hand side of the road.

Parking

57. When a vehicle is parked on a highway, street, or road, it must be clear of traffic lanes. If this is not possible, protection must be furnished by the operator or other employees, using flags, flares, or lights as prescribed by state laws, or other ordinances. Where there are no specific regulations, a red flag in daytime, and lights, flares, or reflectors must be used at night.

58. When parking on a grade, the engine must be shut off, the vehicle left in the gear that will hold it, the hand brake set, and the wheels cramped toward the side of the road or curb. Where necessary, chocks should be placed in the correct position at the rear wheels.

59. When parking, care must be exercised to see that the tires do not bump or scrape the curb.

Backing

60. A vehicle must not be backed until the operator is sure that there are no persons, vehicles, or other obstructions behind it. If necessary, the operator should get out and look behind the vehicle. When an employee, in addition to the operator, is available, he should be directed to give signals to the operator from the ground.

61. If any other vehicle, or a pedestrian, approaches from the rear during the act of backing, they should be given the right-of-way.

91. If ignition wires become broken, temporary repairs may be made by splicing and taping, but the broken wires should be replaced promptly.

92. The storage battery should be kept clean and dry and firmly fastened in the battery box. The connections on the battery terminals should be kept tight and clean.

93. The water level of storage batteries shall be checked once each week in summer and once each two weeks in winter, and additional distilled water added as required. It should be filled to about ⅜ in. above the separators and not too full. After filling, the vent plugs must be replaced and tightened.

94. Storage batteries should be kept well charged, particularly during freezing weather, since the freezing point of the battery water goes up as the state of charge of the battery goes down.

95. A greenish or white deposit on the battery terminals indicates corrosion. Under such conditions, the parts should be soaked with a solution of baking soda or ammonia and cleaned with a stiff brush, being careful that none of this cleaning solution gets into the battery, after which they should be washed with water and wiped dry. Further corrosion can be prevented by covering the parts with a light coating of vaseline or No-Oxide grease. Battery terminals shall be cleaned and greased every two months.

96. A storage battery should not be connected or disconnected from the circuit while the engine is running.

Fuel System

97. The fuel tank, fuel lines and connections must be inspected frequently for leaks.

98. When filling the fuel tank, care should be taken to prevent trash, dirt, or water from getting into the tank. Dirt and moisture should be wiped from the filler cap and tube before filling.

99. The filler cap in the gasoline tank must be kept in place except when filling the tank. The air vent in the cap must be kept open.

100. Excessive use of the choke should be avoided.

Brakes, Wheels and Tires

101. The brakes must be carefully used and kept in correct adjustment. Brake adjustments shall not be made by anyone other than a qualified operator or mechanic.

102. Vehicles equipped with hydraulic brakes must have the fluid levels in the hydraulic brake reservoir checked at least once a month and additional fluid added as necessary. The fluid recommended by the manufacturer should be used in such brakes.

103. Wheels must be checked for proper alinement at least once a year and immediately after any collision.

104. Tire pressure shall be checked daily and the tires kept correctly inflated in accordance with the tire manufacturer's recommendations. A special check of the tire pressure on trucks should be made before carrying heavy loads.

105. Tires must be rotated periodically, including the spare, and repairs made before the wear is excessive. When replacing tires on dual wheels, the tires should be matched, insofar as this is practical.

75. In the absence of specific instructions, crankcase oil should be changed in accordance with the manufacturer's instructions. Where an oil filter is used, greater mileage may be covered, between oil changes. Lighter oil is required during cold weather; heavier oil during hot weather. Seasonal changes in grade should be made as necessary. Transmission and differential lubricants should be changed as required.

76. Never drain the oil or fill the crankcase with oil while the engine is running. Drain the oil while the engine is hot.

77. The oil level should never be permitted to get too low nor too much above the full mark on the oil level indicator. Overfilling a crankcase causes excessive quantities of oil to be thrown against the cylinder walls, resulting in oil pumping, smoking, excessive carbon deposits and fouled spark plugs.

78. To prevent dirt or water from entering the engine while filling with oil, the filler cap and the top of the filler tube should be wiped off before the cap is removed. The filler cap must always be replaced after the oil is put in.

79. If the oil pressure gage fails to register the normal running pressure, the engine should be stopped immediately and the necessary adjustments or repairs made

Cooling System

80. The heat indicator on an automobile, truck, or bus should be watched closely while driving. The normal temperature for most automobiles is about 165 to 180 deg. F. When the heat indicator shows a temperature of 212 deg. F. or higher, the vehicle should be stopped and the cause for the overheating investigated. During freezing weather, high temperatures generally mean frozen cooling solution.

81. Frequent inspection of the cooling system should be made to make sure that the system is not clogged or leaking.

82. It is important that the cooling system be drained and refilled frequently, and at least each 30 days, unless an antifreeze is in use.

83. Each year, before freezing weather is experienced, the cooling system shall be drained and flushed, all connections, such as, hose, gaskets, and pump packing inspected to see that they are tight, and an antifreeze solution, of the type adopted by the company, added to the cooling solution. The quantity added, shall be sufficient to protect against the lowest temperatures to be encountered in the territory in which the vehicle operates. It should be known that the antifreeze used is noninflammable.

84. Cooling solutions shall, during freezing weather, be tested at least once a month and more frequently if the engine has been operated at an unusually high temperature. If required, additional antifreeze shall be added.

85. At the end of the period of freezing weather, the cooling system shall be drained, thoroughly flushed and filled with clean water.

86. When in doubt as to whether the liquid in the cooling system will freeze, it must be tested with a hydrometer, or the cooling system drained.

87. If the liquid in the cooling system gets very low and the engine gets very hot, it should be allowed to cool off for 10 or 15 min. before cold water or cold antifreeze is added. When liquids are added to an overheated engine it should be started and allowed to idle while filling.

88. The radiator cap on an engine should be kept in place. Removal of it does not help to keep the engine cool.

Ignition System

89. The ignition system should be kept dry.

90. All wire connections should be kept tight and free from corrosion.

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Wagon Scrapers)

1. Item of equipment ....
2. Manufacturer ....3. Model .... 4. Type ....
5. Capacity struck ....6. Capacity heaped ....
7. Approx. weight ....8. Drawbar horsepower required ....
9. Type of ejection ....
10. Cable or hydraulic ....11. Length of cutting blade ....
12. Overall length ....13. Overall width ....
14. Overall height ....15. Turning radius ....
16. Number of wheels ....17. Size of tires ....
18. Min. ground clearance ....19. Max. depth of cut ....

Additional information and extra equipment available with costs: ....
....
....
....
....
....

Note: Supplier to furnish full descriptive literature.

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Air Compressors)

1. Item of equipment ....
2. Manufacturer ....3. Model .... 4. Type ....
5. Actual cu. ft. free air per min. ....6. Max. air pressure ....
7. Single or two-stage ....8. Air or water cooled ....
9. Pressure lubricated ....10. Type of main bearings ....
11. Approx. weight ....12. Lifting bale ....
13. Overall length ....14. Overall width ....
15. Overall height ....16. Volume of air receiver ....
17. Type of mount ....18. Gage of mount ....
19. Number of wheels ....20. Width of steel wheels ....
21. Size of pneumatic tires ....22. Wheel base ....
23. Number, bore and stroke: Low-pressure cylinders ....
24. Number, bore and stroke: High-pressure cylinders ....
25. Engine: Gasoline or diesel ....Make and model ....
    Cycles ...... Governed speed ......Horsepower at this speed ....
    Starting ....Voltage of starting system ....

Additional information and extra qeuipment available with costs ....
....
....
....
....
....

Note: Supplier to furnish full descriptive literature.

Report on Assignment 7

Equipment Form to Accompany Purchase Proposal

W. F. Kohl (chairman, subcommittee), Edgar Bennett, N. W. Hutchison, W. B. Lee, F. H. McKenney, V. W. Oswalt, Sr., F. H. Rothe, S. E. Tracy, E. G. Wall.

This is a final report, presented as information.

In order to obtain the same information from all bidders, when the prospective purchaser sends out invitations for bids, the use of the following forms attached to the invitation for bid and to be filled out by the prospective supplier, is suggested. This will enable the prospective purchaser to make a more accurate comparison of the item offered for sale.

The forms included in this report are representative, to be used as a guide, and do not cover all the machines for which such forms might be desirable. The forms can be changed to suit the individual railroad and to include such special equipment and accessories as may be required. It is believed that the use of these or similar forms will prevent the suppliers from substituting lighter or inferior equipment and represent it as being equivalent to that which is called for in the purchase proposal.

The proposal price, terms, delivery, and similar items not covered by the form, should be listed in the prospective supplier's bid.

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Crawler Shovels and Cranes)

1. Item of equipment ....
2. Manufacturer .... 3. Model .... 4. Type ....
5. For shovel: Length of boom .... Length of dipper sticks ....
   Max. dumping radius .... Max. digging radius ....
   Max. dumping height .... Dumping radius at this height ....
   Type of crowd ....
   Mfg., type, size and composition of dipper ....
6. For crane: Total length of boom .... Length of removable section ....
   Min. operating radius .... Capacity at this radius ....
   Max. operating radius .... Capacity at this radius ....
   Hoisting line pull and speed (single line) ....
   Dragline pull and speed (single line) ....
   Mfg., type, size and composition of dragline bucket ....
7. Weight in working condition .... 8. Overall length of track ....
9. Overall width .... 10. Width of track shoes ....
11. Tail swing radius .... 12. Radius of boom foot pins ....
13. Travel speeds .... 14. Swing speed ....
15. Type of hoisting clutches .... 16. Type of swing clutches ....
17. Min. under clearance .... 18. Capacity of fuel tank ....
19. Engine: Gasoline or diesel .... Make and model ....
    Cycles .... Governed speed .... Horsepower at this speed ....
    Starting .... Voltage of starting system ....

Additional information and extra equipment available with costs: ....

....

Note: Supplier to furnish clearance diagram and full descriptive literature.

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Locomotive Cranes)

1. Item of equipment ....
2. Manufacturer ....3. Model .... 4. Type ....
5. Length of basic boom ....6. Lengths of removable sections ....
7. No. of boom point sheaves ....8. Safety glass in cab ....
9. Operator's position in cab: Center .... R. H. side .... L. H. side ....
10. Operating radius: Min. .... Max. ....
11. Capacity: Based on ....Percent of tipping load
    At min. radius: with outrigger .... Without outrigger ....
    At max. radius: with outrigger .... Without outrigger ....
12. Equipped with track clamps ....13. Type of air brakes ....
14. Mfg., model and size of air compressor ....
15. Type of hand brakes .... On ....Wheels
16. Weight in working condition ....17. Ballast furnished by mfg.....By R.R.....
18. Weight on each truck towing ....
19. Total length of car body ....20. Max. width of crane ....
21. Wheel base of trucks ....22. Distance between truck centers ....
23. Size of journals ....24. No., kind and size of wheels ....
25. Tail swing radius ....26. Radius of boom foot pins ....
27. Hoisting line pull and speed (single line) ....
28. Kind of drive: Chain .... Open gear .... Encased gears ....
29. Travel speeds ....30. Shift while moving ....
31. Swing speeds ....32. Type of swing brake ....
33. Max. drawbar pull in low gear ....34. No. of driven axles ....
35. How are controls operated ....36. Steam connection for pile hammer ......
37. Type hoisting clutches ....38. Type swing clutches ....
39. Heating area of boiler ....40. Operating boiler pressure ....
41. Size and type of boiler ....42. Horsepower of boiler ....
43. Coal or oil fired ....44. Make and model of oil burner ....
45. Bore and stroke of steam engines ....
46. Capacity of fuel tank or coal bin ....47. Capacity of water tank ....
48. Engine: Gasoline or diesel .... Make and model ....
    Cycles .... Governed speed .... Horsepower at this speed ....
    Starting .... Voltage of starting system ....
    Additional information and extra equipment available with costs: ....
    ....
    ....
    ....
    ....
    ....

Note: Supplier to furnish clearance diagram and full descriptive literature.

A

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Automobile Trucks)

1. Item of equipment ....
2. Manufacturer ....3. Model .... 4. Type ....
5. Truck size ....6. Gross vehicle weight ....
7. Cab and chassis weight ....8. Length overall ....
9. Distance: Back of cab to rear axle.....10. Distance: Rear axle to end of frame.....
11. Type of body ....12. Type and size of frame ....
13. Number of tires ....14. Size of tires ....
15. Type of wheels ....16. Wheel base ....
17. Auxiliary springs ....18. Type of rear axle ....
19. Kind of brakes ....20. Transmission speeds ....
21. Heater and defroster ....22. Windshield wipers ....
23. Sun visors ....24. Rear-vision mirrors ....
25. Front bumper ....26. Rear bumper ....
27. Engine: Gasoline or diesel .... Make and model ....
    Cycles .... Max. horsepower .... Bore and stroke ....
    No. cylinders........ Oil filter.......... Type of air cleaner ....
    Additional information and extra equipment available with costs ....
    ....
    ....

Note: Supplier to furnish full descriptive literature.

The North and South Railroad Equipment Form to Accompany Purchase Proposal

(Crawler Tractors)

1. Item of equipment ....
2. Manufacturer ....3. Model .... 4. Type ....
5. Horsepower at drawbar ....6. Approx. weight ....
7. Travel speeds (mph.) forward ....
8. Travel speeds (mph.) reverse ....
9. Drawbar pull in low ....10. Method of steering ....
11. Turning radius ....12. Overall width ....
13. Track gage ....14. Width of track shoes ....
15. Ground contact area ....16. Length track on ground ....
17. Ground clearance ....18. No. of truck wheels ....
19. Engine: Gasoline or diesel .... Make and model ....
    Cycles .... Governed speed .... Horsepower at this speed ....
    Starting .... Voltage of starting system ....
20. Angledozer: Cable or hydraulic .... Make and model ....
    Approx. weight .... Blade dimensions ....
21. Power control unit: Cable or hyd. .... Make and model ....
    Number of drums .... Line pull and speed ....
    Approx. weight .... Type of clutches ....
    Additional information and extra equipment available with costs: ....
    ....
    ....

Note: Supplier to furnish full descriptive literature.

Electric Headbolt Heater

The headbolt heater consists of a hollow steel bolt containing an electric heating element. This device is designed to heat the water jacket and is applied to the engine head by replacing a headbolt. Some users claim that this heater is not entirely satisfactory as it does not always provide sufficient heat to the oil in the engine crankcase, and results in insufficient lubrication when the engine is started. It is also claimed that this heater will at times cause the water to boil in the vicinity of the heating rod. The headbolt heater must always be immersed in liquid while connected to the power line, otherwise possible damage to both heater and engine may result. Another type of rod heater is available which is applied through the oil fill-up line and rests in the crankcase. This type of element is claimed to be more satisfactory because it warms the oil in the crankcase and thus an immediate flow of oil is obtained as soon as the engine starts. It has been suggested that this type of heater be used in conjunction with the headbolt heater described above. This combination would probably produce better results than the use of either heater alone.

Portable Hot Air Heater and Dryer (Blower Type)

Another type is the portable hot air heater and blower, which is a self-contained unit, mounted on a frame equipped with a sled bottom and retractable wheels. It is equipped with a gasoline burning heating unit with combustion chamber equipped with turbine type blower operated by a 1½-hp. air cooled gasoline engine. Heat is discharged from the combustion chamber through two pipe outlets to which a hose can be attached for carrying hot air to the desired location. The rated heat output is 100,000 Btu. per hour. This heater has been used with excellent results for warming gasoline and diesel engines. Being of the hot air type, it is particularly suited for safe heating of gasoline engines. However, because of its comparatively high cost, this unit must be kept in constant use to justify its higher cost and adoption for railroad use.

Starting Fluid Primer System

Another system consists of a starting fluid in capsules, a dispenser assembly which punctures the capsules and a plunger type pump to force the vapor through a small nozzle into the combustion chamber of the engine. The vaporized starting fluid is ignited by compression and causes a hot explosion which warms the engine quickly. The fluid is essentially ethyl ether with lubricants and natural fuel added and has a low flash point, providing quick engine starts even at extremely low temperatures. Experience has shown that regardless of temperature the engine will start by this method if the starter will turn the engine over, even at low cranking speeds. One railroad reports that at a temperature of 8 deg. F. below zero a diesel engine was started with the starting fluid in 10 min. while other railroads report that equally satisfactory results are being obtained. One engine manufacturer is equipping diesel engines with the starting fluid primer system at the factory as standard equipment. This system is of comparatively recent origin and its use has been too limited to warrant a definite recommendation. Some difficulty has been experienced in extremely cold weather due to the gelatine composition of the capsule. This problem is being studied with a view to improving the performance and no doubt improvements will be made in the manufacture of the fluid in the near future.

Report on Assignment 8

Devices for Warming Engines to Expedite Starting Equipment in Cold Weather

A. W. Munt (chairman, subcommittee), W. R. Bjorklund, R. E. Buss, Bernard Geier, A. A. Keever, E. H. Ness, T. M. Pittman, J. W. Risk, R. S. Sabins.

This is a final report submitted as information.

Means for warming engines range from the old improvised methods of using hand gasoline blow torches and kerosene torches for warming engine manifolds to the modern semi-automatic permanently installed types of engine heaters in use today; the former being slow, unsatisfactory and sometimes hazardous. Following are descriptions of the various types of engine heaters in use today:

There are about four types of engine heaters generally in use. Many of these heat the engines in the same manner, namely, by heating the water in the cooling system, the only basic difference being in the power or fuel used to operate the heaters. The four types may be grouped and explained as follows:

Electric Immersion Type Block Heater

The immersion type block heater consists of a metal tube which contains an electric heating element. This heater is usually connected to the cooling system of the engine and keeps the water warm when the engine is idle to facilitate starting. These may be obtained in various capacities ranging from 750 watt to 4000 watt and used according to engine temperature requirements desired. These heaters produce excellent results where medium low temperatures are encountered but can only be used where electric power is available. They are adaptable for use with all types of equipment, preferably those equipped with gasoline engines.

Jacket Heater

The jacket heater is located close to the power unit and connected to the cooling system of the engine through a piping arrangement for keeping the water warm. Non-inflammable antifreeze such as ethylene glycol should be used in the cooling system. Jacket heaters are available for burning coal, gasoline, kerosene or butane, with the coal and kerosene types generally being preferred because of safer operation. This type of heater produces excellent results even at low temperatures and the cost of operation is low. It is suitable for use with large units of diesel powered equipment, but is not adaptable to bulldozers and other similar machines.

Manifold Hot Air Heater

The manifold hot air heater, sometimes called a flame thrower, consists of a small tank and plunger pump mounted on the side of the engine, by means of which vaporized fuel oil is forced into an electrode-equipped chamber attached to the engine manifold. The hot blast of fuel ignited by the electrode, which is electrically charged by dry cell batteries, warms up the combustion chamber of the engine and facilitates starting. This type of installation is generally used on large diesel engines and produces excellent results even at low temperatures. Some manufacturers equip diesel engines with this type of heater at the factory.

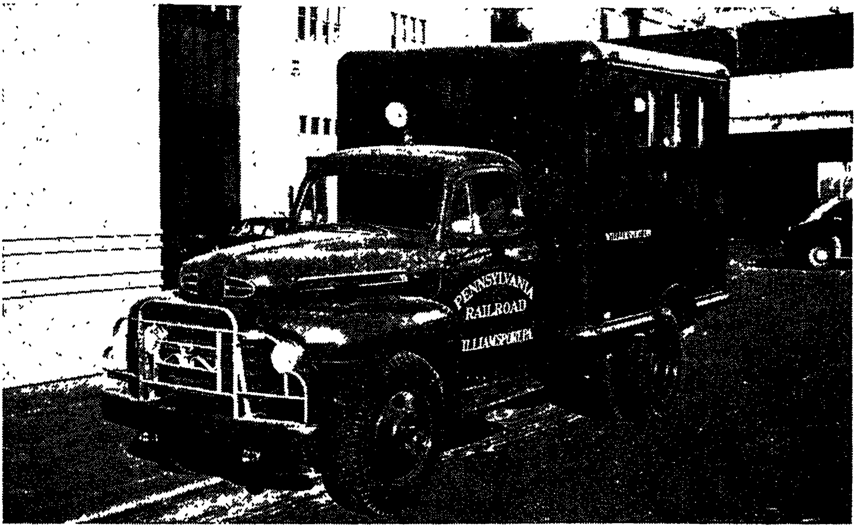

Fig. 1.—Type of Autotruck Most Frequently Provided.

Fig. 2.—The Rear of the Body Should Have Double Doors.

Report on Assignment 9

Off and On Track Equipment and Tools to Maintain Equipment of Mechanized Gangs

A. H. Whisler (chairman, subcommittee), R. M. Baldock, A. J. Flanagan, C. H. R. Howe, P. G. Petri, J. W. Risk, P. S. Settle, Jr., W. I. Stadter, F. F. Zavatkay.

This report is presented as information with the recommendation that the subject be discontinued.

The subject is closely related to, and can be considered as a continuation or projection of, the report "Organization, Machinery and Tools for Repairing Maintenance of Way Work Equipment," (Proceedings, Vol. 47, 1946, pages 182–192).

The extensive use of, and monies invested in, roadway machinery, work and miscellaneous equipment make it necessary that a definite procedure be arranged whereby these machines can be expected to furnish the longest service life with the least amount of out-of-service time. Many machines are worked with large gangs, hence their failure may disrupt an organization and result in unproductive time, costing more than that which is required to repair and return them to active service. Many now commonly used have proved dependable to such an extent that they are, too frequently, expected to operate an indefinite period of time without the proper preventive maintenance or adjustments.

Many machines today are being operated by men improperly qualified or insufficiently trained to get the maximum production from a machine and minimize the amount of repairman service required.

It is essential that a definite program be followed for the periodic inspection, adjustment and minor repair of all roadway machinery and miscellaneous equipment. Proper records must be made of each inspection, of the preventive maintenance performed, fuel and lubricants used, hours worked, etc., to provide proper information for use when subsequent inspections are made.

When there are large mechanized gangs, like or similar to rail-laying organizations using many of the smaller machines, or when gangs are operating the larger and more complicated machines like or similar to the railroad car-mounted track sweepers and ballast cleaners, it is desirable to have a repairman in attendance at all times and cars equipped as mobile repair shops and storehouses for handling replacement parts and materials most frequently required.

One car should be available with its interior designed for proper handling of fuels, lubricants, anti-freeze solutions, etc., together with the larger hand tools and machinery repair parts normally and frequently required. It should be equipped with a vapor-proof electric lighting system, barrel racks and wide side doors for use of a small hand-operated crane for loading or unloading filled barrels. An overhead monorail with movable chain hoist and barrel tongs should be installed to handle loaded barrels and the heavier machine repair parts inside the car. This car need not be heated but must be well ventilated.

Another car should be available as a mobile repair shop, providing space for repairing the smaller machines, such as power track wrenches, adzing machines, rail drills, etc. It should be equipped with wide end doors and side doors, providing for use of a small hand-operated crane to facilitate getting machines into or from the car. It should contain a work bench, electric generator for operating power tools, small lathe, drill

Bench grinder, with abrasive and steel wire wheels
Blow torch
Bolts, assortment of sizes—SAE and standard
Brace and assortment of bits
Brake shoes, track car
Brushes, paint
Bushing drivers
Calipers, inside and outside
Cans, oil, hand
Cans, safety, gasoline
Carburetors, small parts
Chain hoist with tripod
Chipper, small pneumatic
Chisels, cold, set
Clamps, hose, assorted sizes
Cleaner, piston groove
Coils, points and condensers
Combination square and level
Cotter keys, assorted sizes
Drill press and drill bits
Drills, electric, hand
Electric lamp
Emery cloth
Extinguisher, fire
Files, various sizes and types
First aid kit
Gaskets, cylinder head compound
Gages, compression, diesel and gasoline engine
Gages, set, thickness and tapper
Gages, set, track car wheel mounting
Gages, track car wheel tramming points
Generator, electric, tool and light
Generator, electric, welding
Grease cup
Grease gun
Hammer, ball peen
Hammer, sledge
Hand axe
Hatchet
Hose, radiator water
Iron, soldering
Jack, hydraulic, small
Jack, mechanical, hand
Keys, Woodruff, assorted sizes
Ladder
Lathe, small, hollow spindle
Magneto, small parts
Measuring rule and tape
Nails, assortment
Nuts, assorted sizes and types
Oil, kerosene
Oil, lubricating
Oil, penetrating or rust solvent
Oxygen and acetylene welding and cutting equipment
Pipe cutter
Pliers, set
Pullers, gear
Pullers, wheel, set
Pump packing
Punches, set
Radiator sealer and cleaner
Reamers, ridge
Reamers, track car bushing
Ring, compressor
Sand paper
Saws, hack
Screwdriver
Screws, wood and steel, assortment
Shears, tin
Shellac
Solder, stick and wire
Solder, wood, hand
Spark plugs, assorted sizes
Tachometer
Tape, asbestos, friction, rubber
Taps and dies
Tarpaulin
Tow chain or cable
Tubing, fuel line
Valve lifters
Valve refacer
Vise, combination square and pipe
Washers, fiber, assorted sizes
Washers, metal, assorted sizes
Wheels, track car, several sizes
Wire, ignition and primary
Wrench, adjustable
Wrench, chain
Wrench, ignition, set of
Wrench, monkey
Wrenchs, "S," set
Wrenchs, socket, set
Wrench, Stillson
Wrench, 12-point, set
Wrist pin jack

press, valve grinder, etc. It should be equipped with a heating system, preferably not one involving the use of a coal-fired stove. The car should have sufficient windows so that it may be well ventilated and lighted. Bins and cupboards must be provided to hold secure the necessary tools and items of small materials and parts to be carried in the car.

Mechanized gangs not having sufficient machinery to warrant the full-time service of a repairman should be contacted at frequent intervals by a traveling repairman or inspector, to observe the performance of the machines in service and make such field repairs as are practicable. This repairman must have a general knowledge of the operation and construction of all machines working in the territory he has been assigned to cover. He should have at his disposal an autotruck equipped to carry a supply of tools, small parts and materials. Before observing or attempting to repair a machine, he should peruse reports made concerning the operation of the machine since the last inspection and consult with the operator.

Having the operator assisting him, when a second man is necessary, the repairman should make such field repairs as are practicable and which will not require as much machine "lost" or "out-of-service" time as would be consumed by sending the machine to a central repair point. No definite rule can be established as to what repairs should be considered as field repairs and what should be considered as those to be performed only at a central repair shop.

The autotruck most frequently used is of the size normally referred to as the conventional 1½-ton chassis and cab with insulated body, similar to one shown in the illustrations. Some circumstances may indicate a larger vehicle similar to the large mobile machine shops used during World War II by our armed forces is more desirable. The body should be equipped with work bench, racks and cupboards for carrying necessary tools, small parts and materials. Space should be provided for carrying oxygen-acetylene cylinders, together with welding and cutting equipment, small air compressor and an electric generator. The rear of the body should provide for double doors which can be operated from both inside and outside. The inside should be well lighted by large windows in the sides and in each of the two rear doors with which the body should be equipped. Electric lights should be provided on the inside of the body and operated by current from the truck engine. The interior of the cab and body should be heated. The truck engine exhaust pipe should extend no less than four inches above the roof of the body, if the body is lighted and heated by current and heat generated by the truck engine.

When mechanized gangs are using many machines and not frequently moving from one location to another, such as structural steel-welding gangs, ditching or grading gangs, etc., it is desirable that they be provided with portable buildings, approximately 10 by 20 ft., equipped similarly to the railroad cars previously described. These buildings should be skid-mounted, to facilitate their being loaded or unloaded to and from railroad flat cars or heavy-duty, low-bed, highway truck trailers, for movement from one location to another.

No definite list can be compiled as to what tools and materials should be used to equip each railroad car, autotruck and portable building. With a knowledge of the construction and operation of the machines to be serviced, the following list may be used as a guide in determining with what each car, truck or building should be equipped:

Air compressor
Anvil, small
Bar, pin
Bar, pinch
Battery, wet cell
Belting, sect. "V" and flat

Report on Assignment 10

Devices For Unloading Cross Ties

E. L. Anderson (chairman, subcommittee), Edgar Bennett, W. S. Brown, W. M. Dunn, A. A. Keever, A. W. Munt, T. M. Pittman, J. R. Rushmer, G. M. Strachan.

This is a final report, presented as information.

As of the present, no commercial devices for unloading cross ties on line of road are generally in use. Various hand tools are being used to assist in handling cross ties, one such being the ordinary hand tongs that can be hooked into the side or end of the tie as shown in Fig. 1. This and other similar devices minimize creosote burns and other personal injuries.

Several roads report the use of grapples for handling ties by means of power cranes. These grapples are made by several different manufacturers, and are also homemade by some railway companies. The commercial types were principally developed for use in handling pulpwood but have been used in many instances for handling ties. They are adapted particularly for loading secondhand ties into cars in conjunction with a power crane. It is necessary with these grapples, however, that care be used in unloading new ties because of possible damage to the ties. (See Fig. 2..)

Fig. 1. (Left).—Hand Tongs. Fig. 2 (Right).—Grapple.

Fig. 3.—The Body Should Be Equipped with Cupboards for Carrying Tools, Parts and Materials.

Fig. 5.—Specially Designed Car to Facilitate Unloading of Ties.

One road reports the development of a homemade tie unloading device with which it is still experimenting. This device consists of a bracket hooked to the side of an open-top gondola car and a supporting lever, which carries an adjustable chain equipped with tie tongs. (See Figs. 3 and 4.) Fig. 3 shows the timber dog applied to the tie near the end and the leverman raising the end of the tie to rest on the side of the car. Fig. 4 shows the timber dog being reset near the center of the tie, and the leverman ready to slide the tie up on the side of the car where the timber dog is jerked off and the tie allowed to slide to the ground.

One railroad reports the use of slings and power cranes in unloading ties out of ballast cars. In this case the slings are returned to the treating plants in the cars and the ties are loaded with a sling placed around the ties so that the power crane may be used readily for handling the bundles of ties on the line of road.

Several railroads are using cranes for unloading ties to be inserted in yards where they cannot be distributed at the actual point of insertion. Various methods are used in such cases. In some instances, ties are bound in bundles by light steel straps when loaded into cars at the treating plants, and the crane is used for unloading. In other instances slings or grapples are similarly used in picking up unbundled ties by means of a crane, as shown in Fig. 2.

An investigation of methods used for unloading ties on the line of road, shows that the most prevelant method at the present time is to unload them by hand out of gondola cars, although some roads report the use of practically any type car available; such as stock and box cars. In some instances, special type cars are being used to facilitate the unloading. These special type cars fall under the following classifications:

1. Standard flat cars with rack ends and side stakes temporarily applied.
2. Standard flat cars with special removable rack panels.
3. Standard gondola cars with parts of the side walls removed.
4. Special designed flatbottom cars with permanent rack ends and side stakes. See Fig. 5.

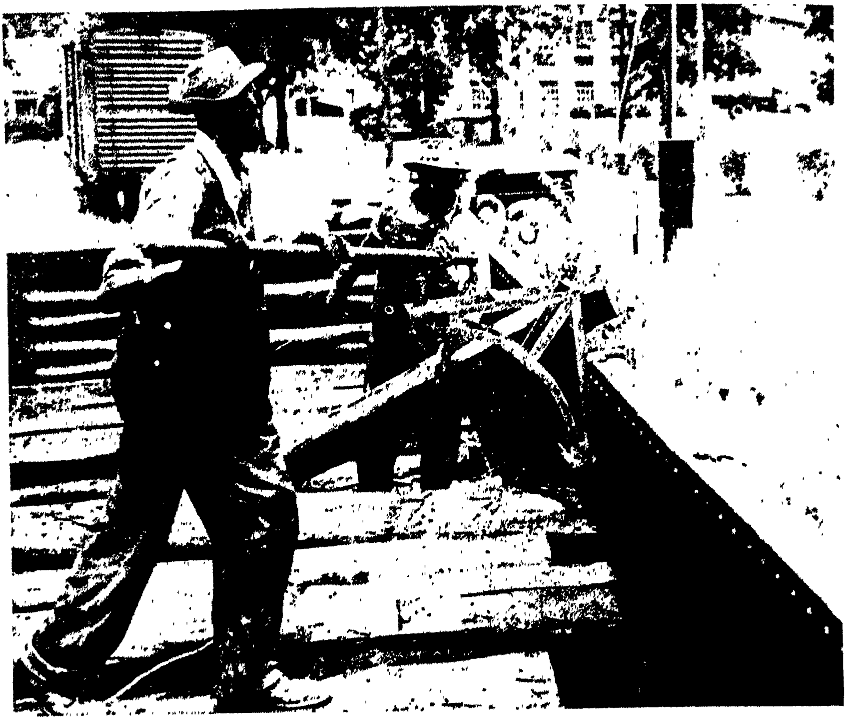

Fig. 3.—Homemade Tie Unloading Device—Initial Position.

Fig. 4.—Homemade Tie Unloading Device—Advanced Position.

Report of Committee 30—Impact and Bridge Stresses

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Viaduct columns, collaborating with Committee 15.

   No report.

2. Steel girder spans with open decks and with ballasted decks.

   Progress report, presented as information .... page 288

   Report on aluminum and steel girders (Appendix A) .... page 290

3. Dynamic shear in girder and truss spans.

   Progress report, presented as information .... page 288

4. Impact and bending stresses in columns and hangers of truss spans.

   Progress report, presented as information .... page 288

5. Concrete structures, collaborating with Committee 8.

   Progress report, presented as information .... page 289

6. Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8 and 15.

   No report.

7. Stresses and impacts in timber stringer bridges, collaborating with Committee 7.

   No report.

8. Steel truss spans with open decks and with ballasted decks.

   Progress report, presented as information .... page 289

9. Distribution of live load in transverse floors and longitudinal stringers.

   No report.

10. Stresses in lateral bracing of bridges.

    No report.

The Committee on Impact and Bridge Stresses,
J. P. Walton, *Chairman.*

AREA Bulletin 484, December 1949.

From the investigation conducted so far, it is evident that there is not now on the market any mechanical device developed for exclusive use in handling ties on the line of road. Such devices that have been used, outside of the commercial grapples and hand tools, are equipment that the railroads have purchased for other purposes and brought into service for unloading ties. These devices are generally used in yard work.

Roads reporting the use of special cars state they are of great assistance in unloading ties, saving in labor and work train expense, with a reduction of personal injuries. Special tie cars are of great benefit but necessarily require a large expenditure for cars and likewise result in costly transportation in moving the cars empty back to plants.

It is the recommendation of your committee that, due to the urgent necessity for economy in handling cross ties on line of road, and the desirability of minimizing unloading hazards, the various railroads endeavor to develop methods for handling cross ties that most nearly meet their needs.

It is also recommended, in the interest of economy in handling ties on the line of road and to reduce personal injuries to the minimum, that where gondola cars are used for shipping ties and they are to be unloaded by hand, such use be confined to low side gondola cars whenever possible.

A report on the failures in the floorbeam hangers of pin-connected truss spans was prepared jointly by Purdue University and the AAR research staff and sent to all chief engineers during the year. A similar report of failures in the floorbeam hangers of riveted spans will be sent to the chief engineers in the near future.

Report on Assignment 5

Concrete Structures, Collaborating with Committee 8

Tests were made during 1949 on two reinforced concrete structures whereby the static and dynamic stresses were measured in both the concrete and reinforcing steel. The two structures tested were a four-span continuous reinforced concrete subway at Flint, Mich., on the Grand Trunk Western Railroad, and a precast reinforced concrete trestle on the Chicago & North Western Railway.

Progress is being made in the analysis of the accumulated data, and a report of these tests will be presented as soon as possible.

Report on Assignment 8

Steel Truss Spans with Open Decks and with Ballasted Decks

The static and dynamic stresses were measured in the chord members of two truss spans on the Texas & Pacific Railway and a report of these tests will be presented later under Assignment 3.

The stresses in the members of a 246-ft. 6-in. double-track through truss draw span on the Elgin, Joliet & Eastern Railway were measured under the operation of two parallel double-headed test trains at speeds not exceeding 20 mph. These tests were conducted at the request and expense of the railway. A summary of these results will be published.

The stresses in the members of one 520-ft. arch span of the Eads bridge across the Mississippi river at St. Louis, Mo., were measured under regular trains and under two parallel double-headed test trains at speeds not exceeding 15 mph. These tests were conducted at the request and expense of the Terminal Railroad Association of St. Louis. A summary of these results will be published.

The stresses were measured in the counterweight truss members of a 219-ft. 4-in. double-track bascule bridge on the Illinois Central Railroad to determine the primary and secondary effects of the concrete counterweight during the opening of the bridge. The tests were conducted at the request and expense of the railroad. A summary of these results and the results in a bascule bridge on the Peoria & Pekin Union Railway will be published.

Ralph W. Mabe

The committee directs attention to the memoir to Mr. Mabe appearing in the annual report of the Committee on Iron and Steel Structures.

Report on Assignment 2

Steel Girder Spans with Open Decks and with Ballasted Decks

A report of the investigation of static and dynamic effects in one 100-ft. steel girder span and one aluminum girder span of the same length appears as Appendix A to the report of your committee. The conduct of the tests, analyses of the data and preparation of the report were carried out entirely by personnel of the Aluminum Company of America. It is realized by your committee that these tests were conducted under a locomotive at relatively low speeds. However, it was felt that the comparison of the stresses, deflections and vibration characteristics in the same length steel and aluminum spans under the same loading conditions would be of extreme interest to the bridge engineers. Accordingly, permission was requested from and granted by the Aluminum Company of America to publish the results of these tests by your committee.

A report of the investigation of static and dynamic effects in three deck girder spans under high speed diesel and steam locomotives on the Chicago & North Western Railway is completed and will be published in a summer bulletin.

Report on Assignment 3

Dynamic Shear in Girder and Truss Spans

Tests were made during 1949 on the web members of a 125-ft. single-track through truss span and a 122-ft. 9¾-in. single-track through truss span under high speed steam locomotives on the Texas & Pacific Railway. The tests were made at the request of the railroad and the data were completely analyzed by its bridge department under the guidance of the research staff of the AAR. The results of these tests will be included in a future report of your committee.

The dynamic shears were measured in the webs of the deck girder spans on the Chicago & North Western Railway and a report of these tests will be presented later under Assignment 2.

Report on Assignment 4

Impact and Bending Stresses in Columns and Hangers of Truss Spans

The static and dynamic stresses were measured in the floorbeam hangers of the two single-track short truss spans on the Texas & Pacific Railway in connection with the tests made under Assignment 3.

The research staff of the AAR collaborated with Purdue University during the past year in determining the effect of reducing the sharp re-entrant cut on the channel flanges of the floorbeam hanger of a truss span on the Atchison, Topeka & Santa Fe Railway near Ponca City, Okla., and the results of these tests can be found in the annual report of Committee 15.

TABLE 1.—TENSILE PROPERTIES OF ALUMINUM ALLOY 14S–T6 PLATES AND SHAPES USED IN GRASSE RIVER BRIDGE GIRDERS

Material	Specimen Direction	Yield Strength (Offset-0.2), psi.	Ultimate Strength, psi.	Elongation in percent	
				2-in. Gage	8-in. Gage
¾-in. Web plate (Alclad)	Longitudinal	62, 300	69, 200	16.6	9.4
	Transverse	62, 400	69, 600	15.8	8.8
⅝-in. Cover plates (Alclad)	Longitudinal	58, 800	66, 200	17.5	9.8
	Transverse	59, 600	67, 900	10.1	6.5
8 x 6 x ⅝-in. Flange angles (nonclad)	Longitudinal	67, 600	74, 500	16.1	10.1

Standard tension test specimens of rectangular cross section with 8-in. gage length used. ASTM Specification E 8–46.

Values shown are average of 6 to 12 tests from different lots of each material. Variations between individual strength values and averages ranged from 1 to 3 percent in most cases; maximum variation was 5 percent.

It is noteworthy that the aluminum span was completely shop fabricated and shipped in one piece to Massena, ready for erection. The finished weight was only 53,000 lb. Since the corresponding weight of the 98-ft. steel spans was 128,000 lb., it was necessary to ship the steel girders separately and to install the cross frames and lateral bracing after the girders were in place on the piers.

Although a demonstration of the suitability of aluminum alloys for railway bridge structures involves many factors, some of which can be evaluated only by long-time observations, it was believed that some information of immediate value might be obtained from comparative field tests of the aluminum and 98-ft. steel spans. A comparison of measured strains and deflections would show the applicability of the design procedures used and would emphasize the important fact that the structural behavior of aluminum alloys is as predictable as is generally assumed to be the case for steel.

One of the problems of immediate interest in the field of railway bridge design concerns the allowance to be made for impact under moving loads. The Association of American Railroads is engaged in extensive field tests of bridges of different types and spans in an effort to develop a more satisfactory impact formula for design use.[3, 4, 5] Although the Grasse river bridge, because of its location on a curve near the end of the line, is not suited for moving-load tests at high speeds, an investigation of impact effects under such speeds as were attainable was highly desirable.

The design computations indicated that the maximum vertical deflection of the aluminum span under the E 60 design live load would be about 2.7 times that for the corresponding steel span. Since the natural frequencies of vibration for the girders as a whole should be inversely proportional to the square root of the deflections,[4] a condition of resonance between natural frequencies and frequencies induced by moving loads would be more probable on the aluminum span than on the steel span because it would occur at lower speeds. The practical importance of this difference in behavior depends on the damping characteristics of the structure itself, as well as on the damping effects of the live load. Factors of this nature can be evaluated most satisfactorily by experiment. Since the aluminum girders are the first to be used in a class of bridge structure where vibration characteristics and impact effects are of particular interest, some attempt to compare the natural frequencies of vibration and the damping characteristics of the aluminum and steel spans was considered to be within the scope of these tests.

Appendix A

Tests of Aluminum and Steel Railway Bridge Girders

By E. C. Hartman,* R. L. Moore,* and F. E. Rebhun*

Aluminum Company of America Research Laboratories, Engineering Design Division

Introduction

In the fall of 1946, construction was completed on the Massena Terminal Railroad Company's new crossing over the Grasse river at Massena, N. Y. The unique feature of this bridge which consists of seven deck plate girder spans, is that one 97.5-ft. span is built entirely of aluminum. The remaining spans, ranging from 73 to 98 ft. in length, are of conventional steel construction. Since the aluminum girders are the largest ever built, as well as the first to be used as part of a railroad bridge, their design and fabrication presented a number of new problems.

The decision by Aluminum Company of America to include an all-aluminum span in the Grasse river bridge was based largely on a desire to demonstrate that the high strength aluminum alloys are suitable for use in heavy-duty structures. It was recognized that the combination of aluminum and steel spans of nearly the same length in the same bridge would provide unexcelled opportunities for comparisons of performance and serviceability. The experience to be gained from the design, fabrication and erection of an aluminum bridge of this size would be invaluable, moreover, in extending the use of structural aluminum to new fields.

Although the primary purpose of this paper is to present the results of the tests made on the bridge in September 1947, a brief review of some of the outstanding design and construction features of the aluminum span will perhaps not be amiss.† It should be emphasized that the bridge is a single-track structure, designed for Cooper E 60 loading. The aluminum span was built entirely of Alclad 14S–T6 plate and nonclad 14S–T6 alloy extruded and rolled shapes. Table 1 summarizes the results of some of the tensile tests made on samples of the material supplied to the bridge fabricator. Because of the high strength of this alloy, having a specified minimum yield strength of 57,000 psi. for the plate and 53,000 psi. for the shapes, a basic unit stress in tension of 21,000 psi. was used in design. The corresponding design stress for the ASTM A 7 steel spans was 18,000 psi.

In view of the difference in modulus of elasticity of aluminum and steel and its effect on vertical deflections, the aluminum girders were made approximately 1 ft. deeper than the adjacent 98-ft. span steel girders (121¾ in. for aluminum vs. 110$\frac{1}{16}$ in. for steel). The gross cross-sectional area and moment of inertia at the center of the aluminum girders, however, were slightly less than for the steel girders.

In addition to the conventional pairs of vertical stiffeners used on the webs of both girders to resist shear buckling, a single-angle longitudinal stiffener was used on the upper portion of the aluminum web to provide greater stability against buckling under longitudinal compression.

The aluminum girders were fabricated in the Rankin Shops of the Bethlehem Steel Company, using the same equipment and following, with a few minor exceptions, the procedures employed in the fabrication of the companion steel girders. Most of the aluminum rivets were ⅞-in. diameter A17S–T4 alloy, driven cold with a squeeze riveter. Where the squeeze riveter could not be used, ⅞-in. diameter rivets of 53S alloy were driven hot with pneumatic hammers.

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* Chief, engineering design division; senior research engineer, and research engineer; respectively.
† See reference notes at end of this monograph.

Observation Stations

Figs. 1 and 2 show different views of the test spans and the observation platforms from which all measurements of strain and deflection were made. The platforms and auxiliary scaffolding at the center of the spans permitted ready access to the entire mid-section of the downstream girders. These stations were reached by means of a walkway supported on the bottom flange lateral bracing and running continuously from the rear end of the bridge. The tarpaulins shown were used to provide protection from wind and rain.

Fig. 2.—Partial View of Grasse River Bridge Showing Observation Stations at Center of and Midway Between Test Spans.

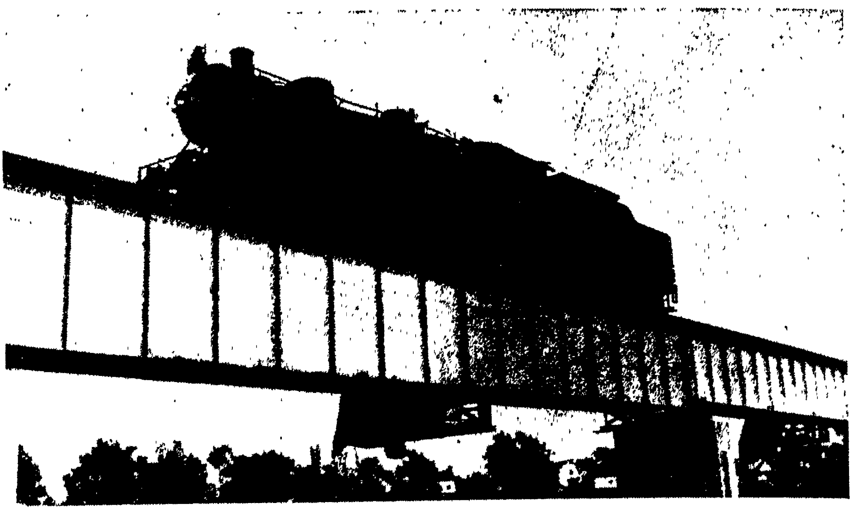


Fig. 1.—Locomotive Used for Static and Moving Load Tests. Overall length 82 ft.; total weight 457,000 lb. (N. Y. C. No. 1871, Class H–6–A)

The test program included the following determinations:

1. The measurement of primary bending stresses and vertical deflections near the center of the downstream girders of each test span under static and moving loads.
2. The measurement of transverse bending stresses in the inside fillets of the top flange angles of the same two girders under static wheel load concentrations.
3. An investigation, by means of a mechanical oscillator, of the vibration characteristics of the aluminum and steel test spans under both dead load and live load conditions.

Procedure

Test Loads

Fig. 1 shows the steam locomotive obtained from the New York Central Railroad for the static and moving-load tests. The 100-ton diesel locomotives of the Massena Terminal Railroad, in regular service over the bridge, were not used because of their light weight as compared to the E–60 loading for which the bridge was designed. The diesel locomotives, moreover, would not produce the dynamic effects, commonly known as hammer blows or dynamic augments, which characterize the action of conventional steam locomotives having unbalanced drivers.

The total weight of the test locomotive was determined on track scales prior to the start of the tests to be 457,000 lb., which was 31,000 lb. heavier than an E 60 locomotive. Since the tests were made with a single locomotive, however, the maximum bending moment attainable was computed to be only about 75 percent of the live load design value. The axle loads shown in Fig. 3 were obtained by computation from the weight-distribution figures furnished by the New York Central and the actual weights determined separately for the engine and tender. It is of interest to point out that the scale weight for the engine was only 4500 lb. or 1.5 percent greater than the rated value. The axle loads shown for the tender were obtained by dividing the scale weight by four.

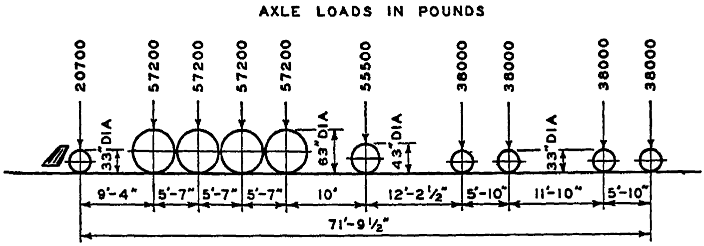


Fig. 3.—Loading Diagram for Steam Locomotive Used in Tests of Grasse River Bridge.

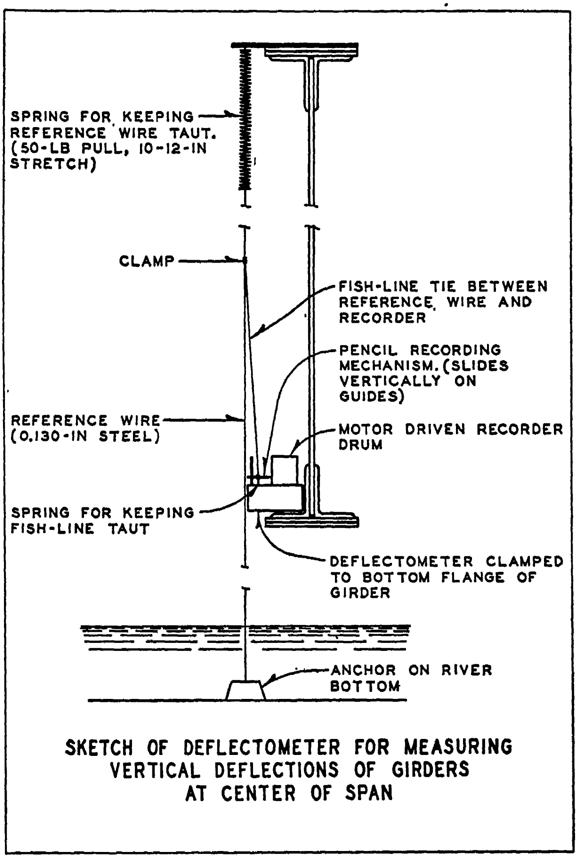


Fig. 4.

Deflection Measurements

A deflectometer, sketched in Fig. 4, was used to measure the vertical deflections of the test girders under static and moving loads and to determine the amplitude of the oscillations produced in the vibration tests. Only one instrument was used but it could be moved readily from one girder to the other as desired, since the attachment to the tension flange was made by C-clamps. The recorder was built at the Aluminum Research Laboratories many years ago by R. L. Templin in connection with the measurement of conductor cable vibrations and minor changes were made to adapt it to these tests.

Strain Measurements

Strains were measured by means of Baldwin Southwark SR–4 bonded wire resistance strain gages, Types A–1, A–7, and A–12. The procedure for attaching the gages involved smoothing the painted surfaces of the girders with emery paper and cleaning lightly with mineral spirits. The gages were then attached by means of a pyroxylin cement recommended especially for this purpose. Since the webs of both the aluminum and steel girders were spliced at midspan, sections 28 to 30 in. off the center were selected in order to avoid to some extent the disturbing influence of the splice plates on stress distribution.

The strains indicated by the wire gages in the static tests were measured by means of a Baldwin Southwark SR–4 strain indicator. The strains for the moving-load tests were determined by means of a General Electric two-element strain amplifier and recording oscillograph. Measurements of this latter type were confined to the three gages located on the tension flange of each test girder.

Stresses corresponding to the strains indicated by all longitudinal gages were obtained by multiplying the values of measured unit strain by moduli of elasticity of 10,600,000 psi. and 29,000,000 psi. for the aluminum and steel. Transverse stresses in the fillets of the top flange angles were based on a consideration of both longitudinal and transverse measured strains.

Vibration Tests

The investigation of the vibration characteristics of the test spans was carried out using a mechanical oscillator designed and built at the Aluminum Research Laboratories for these determinations. The machine consisted of a single eccentric arm which could be rotated at various speeds and to which different weights could be attached to provide a wide range of oscillating forces. The unit was mounted on the tension flanges of the girders through a framework of steel and timber beams. Power for the oscillator was provided by a 3-hp. air motor, driven by a portable air compressor. Rotational speeds were determined by means of a voltmeter tachometer.

The general procedure followed in determining the natural frequencies of the test spans under dead load, or under the 100-ton live load obtained by placing one of the Massena Terminal Railroad Company's diesel locomotives on the span, was to make a trial run with the oscillator at gradually increasing speeds up to and beyond the natural frequency. The run was then repeated and strain and deflection amplitude readings taken. The strain readings were limited to the same three gages that were used in the moving-load tests and records were obtained as before by means of the recording oscillograph. Deflection amplitudes at the center of span were determined from a 4 to 6-in length of deformator record taken at each oscillator speed.

In all cases the vibration characteristics were investigated for several combinations of weights on the oscillator arm. Under dead-load conditions on both spans the vibration of the scaffolding and loose walkways at the natural frequencies of the bridge made the action seem quite violent, although the actual amplitudes of vertical movement involved were not large. Once the natural frequency of the span was reached it was

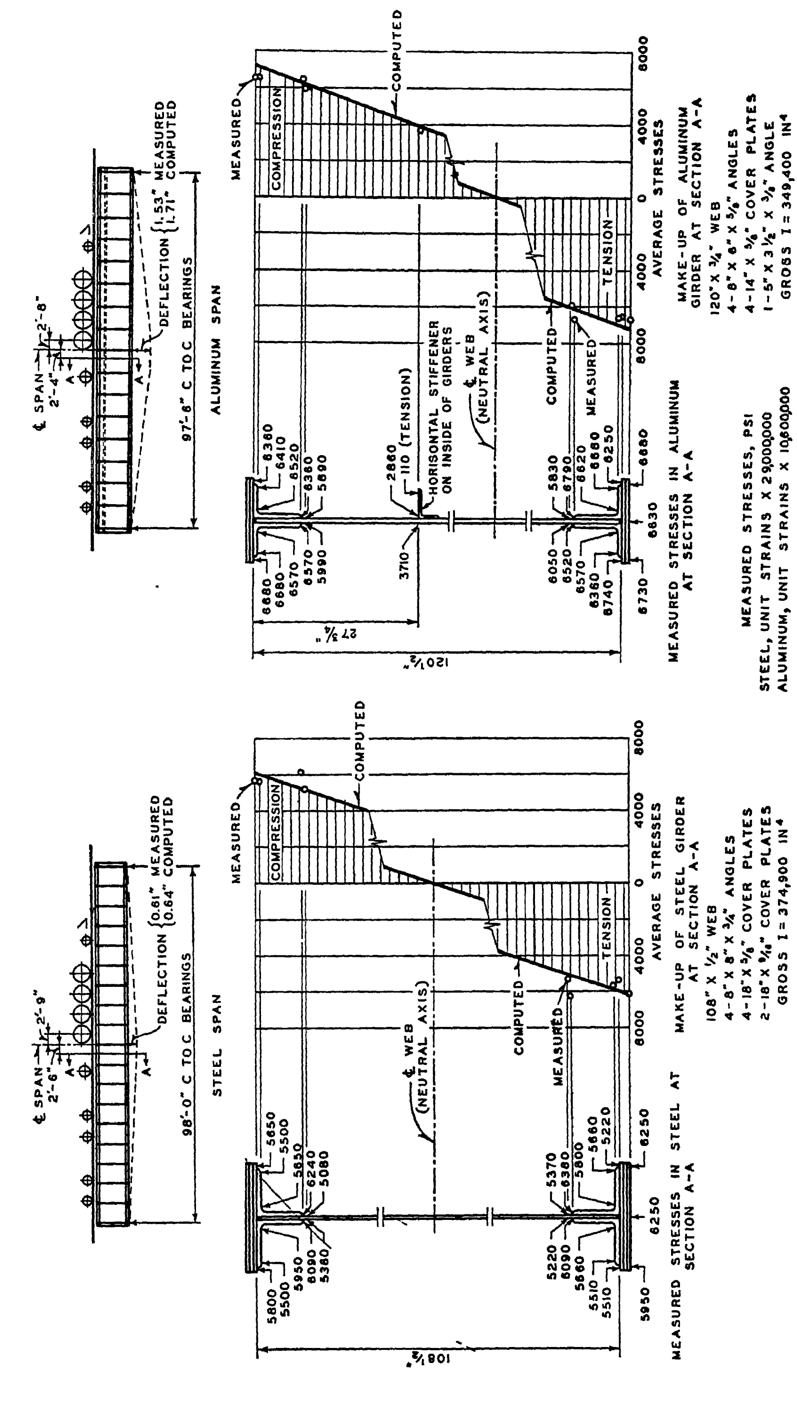


Fig. 5.—Bending Stresses and Deflections from Static Tests—Grasse River Bridge.

difficult to increase the speed of the oscillator only slightly to throw it out of synchronism with the bridge. Speeds immediately above the natural frequencies were usually obtained by over-running the next speed increment appreciably and approaching the desired value from the high, rather than from the low side.

Results and Discussion

Static Tests

Fig. 5 shows the primary bending stresses and deflections measured near the center of the test spans for the position of the locomotive which produced the maximum tensile strains in the wire gages on the bottom cover plates. These load positions were determined by trial and, as indicated, were essentially the same for the two girders. Computations indicate that stresses about one percent greater would have been obtained had the rear driver been spotted directly over the strain-gage sections but the distribution through the track apparently obscured this small increase.

The individual measured stresses shown in Fig. 5 indicated a reasonably uniform distribution across the width of the flanges and through the thickness of the webs. The averages of these measured values, moreover, were in fair agreement in most cases with the computed stresses, based on the properties of the gross sections given in Reference 2 The latter observation is of some interest in that the net tensile stress computed for the extreme fibers of the aluminum girder, on which the design was based, was 25 percent higher than the corresponding computed gross compression stress.

The stresses measured in the cover plates and in the outstanding legs of the angles of both girders averaged 6 to 8 percent less than the gross computed values whereas those measured in the vertical legs of the flange angles were greater than computed by amounts averaging 6 percent for the aluminum and 20 percent for the steel. The average stress gradient through the depth of the flanges, therefore, was not as steep as that computed. The fact that the stresses representing the greater part of the flange area in both girders were a few percent less than those computed indicates that either the bending moments produced by the test locomotive were not as great as computed from the loads shown in Fig. 3, or that because of the participation of the lateral bracing systems the effective moments of inertia were greater than the nominal design values.

Fig. 5 also shows the measured vertical deflections at the center of the spans. The value of 1.53 in. observed for the aluminum girder is about 10 percent less than that computed, using gross moment of inertia and including a computed allowance for shear amounting to about 7 percent of the bending deflection. The measured deflection of 0.61 in. for the steel girder is about 5 percent less than that computed using gross moment of inertia and including an allowance for shear amounting to about 11 percent of the bending deflection. It is evident from these measurements that the ratio of deflections for the two girders was about 2.5 to 1 instead of 2.7 to 1 as indicated in the design computations.

It should be emphasized that the steel girder was spliced in the web at the center of the span only and that the flange angles and cover plates were continuous. The web of the alumnium girder, on the other hand, was spliced at three points and each flange angle was spliced at two points. As a result approximately 30 ft. of splice material were added to each aluminum flange. If this extra material were 100 percent effective, the computed moment of inertia at the spliced sections would have been increased from 7 to 12 percent. Although an assumption of complete integral action is probably not warranted, it nevertheless seems reasonable to believe that the splice plates contributed something to the flexural stiffness of the aluminum girder.

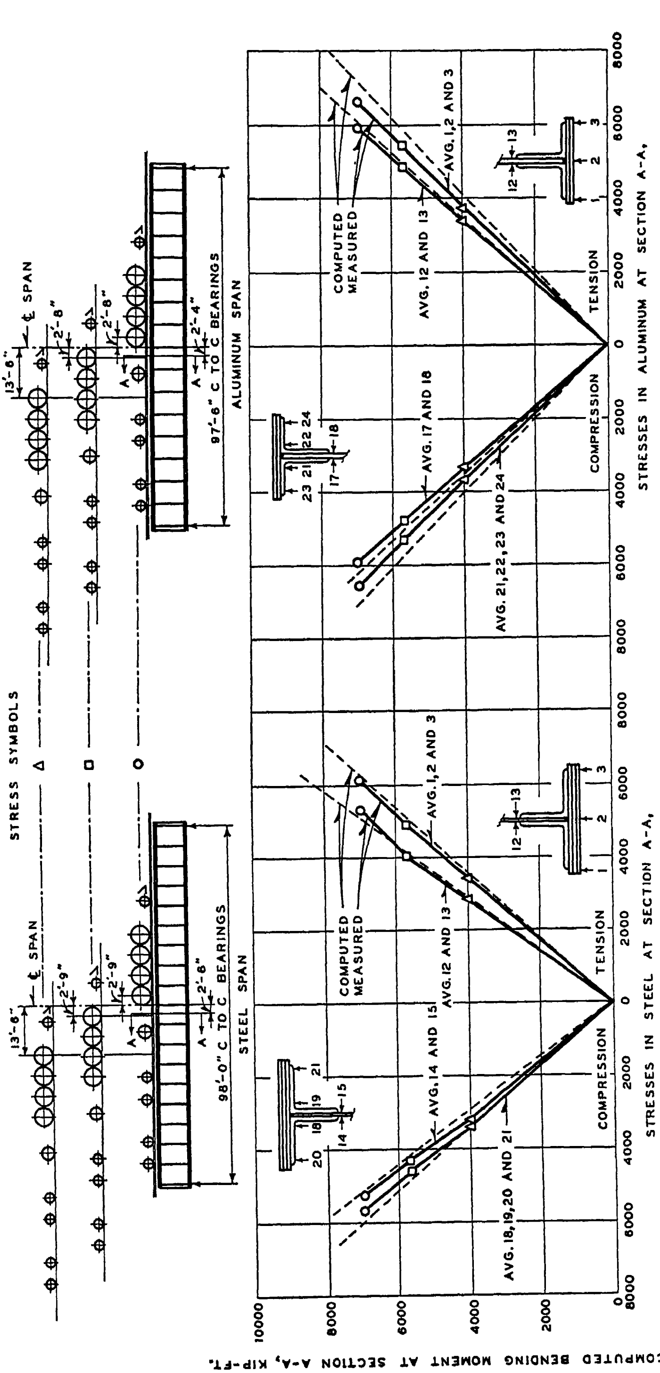


Fig. 6.—Bending Stresses for Different Positions of Locomotive in Static Tests—Grasse River Bridge.

The participation of the lateral bracing systems, although a very indeterminate factor, would tend to make both the observed stresses and deflections less than computed. Although no attempt was made to evaluate this secondary effect, some indication of its possible significance may be obtained from the fact that eight gusset plates, each ⅜ in. by 20½ in. by 3 ft. 10 in., were riveted to the top flange of the aluminum test girder foı the attachment of lateral bracing members. Some portion of these 20½-in. wide gusset plates, having a combined length equål to 31 percent of the span, was undoubtedly effective flange area. The top flange gussets on the steel girder should have been less effective because they were only 17½ in. wide by ⅜ in. thick and their length equalled only 26 percent of the span. Furthermore, they were attached to flanges which at the center of span had a cross-sectional area 62 percent greater than the flange area at the center of the aluminum span. It does not seem unreasonable to believe, therefore, that the secondary stiffening effect of the gussets and laterial bracing members in the aluminum girder was relatively greater than in the steel girder.

Fig. 6 shows additional comparisons between measured and computed primary bending stresses for the two girders. These results are of interest mainly because they show the three positions of the locomotive investigated on each span. The position nearest the center is the same as that shown in Fig. 5.

The data tabulated in Fig. 7 give some indication of the nature of the transverse bending produced in the inside fillets of the top flange angles under static wheel-load concentrations. None of the transverse strains measured in the aluminum flange were high enough apparently to offset the Poisson's ratio effect (tensile strains) accompanying the overall longitudinal compression in the flange. In the steel girder, however, compressive strains of small magnitude were measured in the fillets.

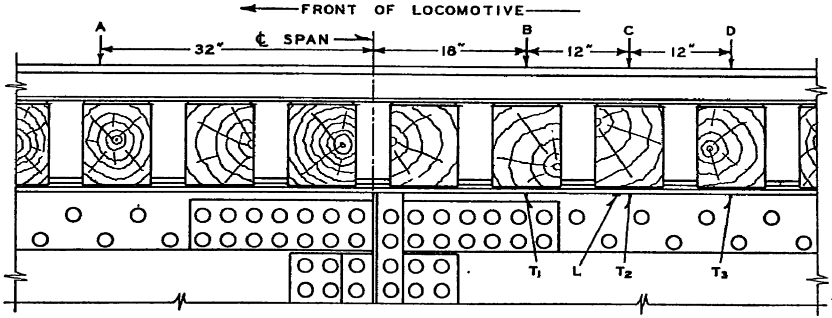
It seems reasonable to assume that neither of the girder flanges was capable of resisting a high load concentration at the outstanding edges and for that reason the greater part of the tie reaction was probably carried directly by the web. Under such conditions, the outstanding flange would be bent to conform approximately to the deflected shape of the ties and the angle change between the flange and web would probably not be far different for the two girders. If such were the case, the transverse bending stresses in the fillets of the steel flange would be larger bceause of the higher modulus of elasticity of the steel.

Moving-Load Tests

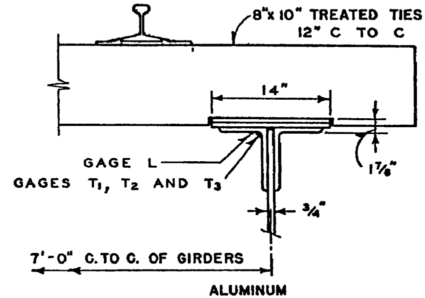
Fig. 8 shows traces of a number of the strain records obtained in the moving-load tests. As previously indicated, these measurements were limited to the three wire gages on the bottom cover plate of each girder near the center of the spans.

The procedure followed was first to establish reference lines of zero and maximum static live load strain. This was accomplished by exposing a short length of film to the strain signals produced with no load on the bridge and with the locomotive in the position producing the maximum strain as determined from the static tests. The locomotive was then run across the bridge and the remainder of the film exposed. This process was repeated on each span until a representative set of strain records was obtained. Those shown in Fig. 8 were traced directly from the films, the only modification being to superimpose the zero load and static live load strain reference lines on the moving-load portion of the diagrams.

The deflectometer charts shown in Figs. 9 and 10 were also traced directly from the field records. The wide variations in length of diagram in some cases resulted from the fact that the speed of the recorder drum was not constant.



GAGES T_1, T_2 AND T_3 (¼-IN.) CEMENTED TO INSIDE FILLET, NORMAL TO DIRECTION OF PRIMARY BENDING STRESS.
GAGE L (1-IN.) NEAR FILLET BUT PARALLEL TO DIRECTION OF PRIMARY BENDING STRESS



POSITION OF REAR DRIVER	MEASURED STRAINS, IN. PER IN.*				MAXIMUM ** STRESS IN FILLET, PSI
	L	T_1	T_2	T_3	
	ALUMINUM				
A	-.000615	+.000085	+.000135	+.000125	-1400
B	-.000610	+.000025	+.000090	+.000120	-2100
C	-.000605	+.000040	+.000080	+.000115	-1900
D	-.000600	+.000050	+.000085	+.000105	-1800
	STEEL				
A	-.000195	——	——	——	——
B	-.000190	-.000060	-.000030	+.000005	-3700
C	-.000185	-.000050	-.000035	.000000	-3400
D	-.000190	-.000045	-.000025	+.000005	-3300

* + TENSION, − COMPRESSION.
** TRANSVERSE STRESS DETERMINED FROM USUAL BIAXIAL STRESS RELATIONSHIP

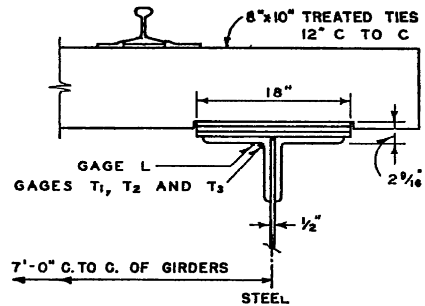


Fig. 7.—Local Bending Strains in Fillets of Outstanding Flanges under Locomotive Drivers—Grasse River Bridge.

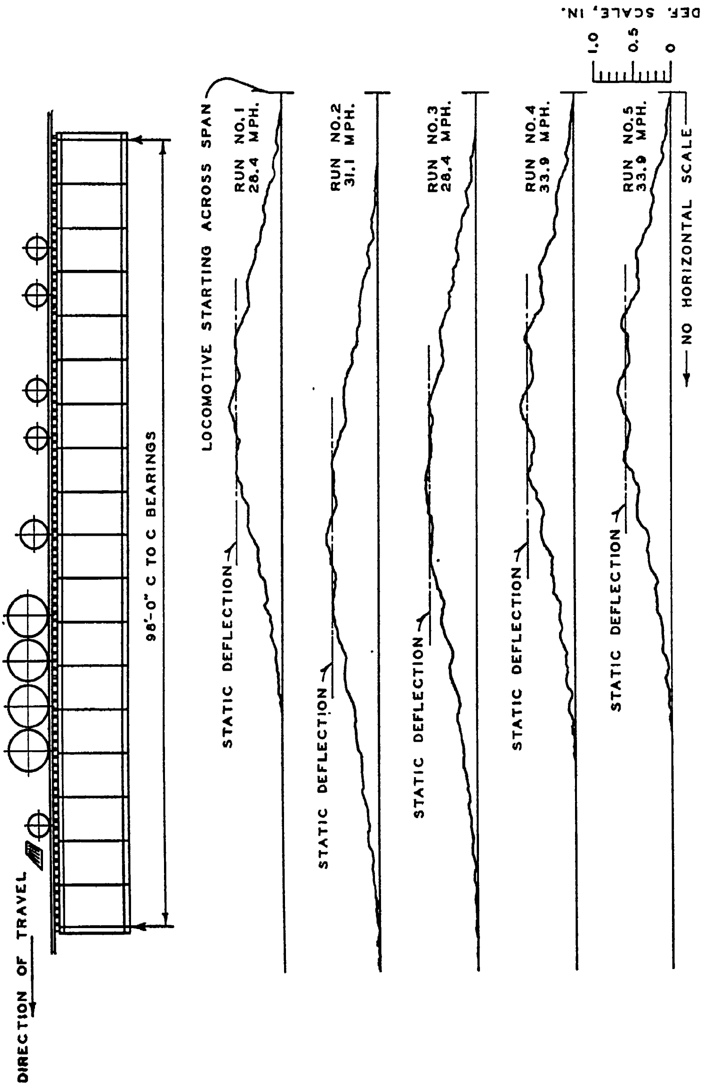


Fig. 10.—Deflectometer Records for Moving Loads over Steel Span—Grasse River Bridge.

The locomotive speeds indicated for the different runs were determined by noting with a stop watch the time required for the locomotive to pass over the two test spans. The maximum speed of 33.9 mph. attained in two runs over the steel span was considerably above the speed normally used on the bridge. Test runs at speeds above the limit indicated were not considered advisable.

Although it is somewhat easier to follow the dynamic effects of the unbalanced locomotive drivers across the aluminum girder, because of the greater strains and deflections produced, the maximum impact effects or increases over static values were essen-

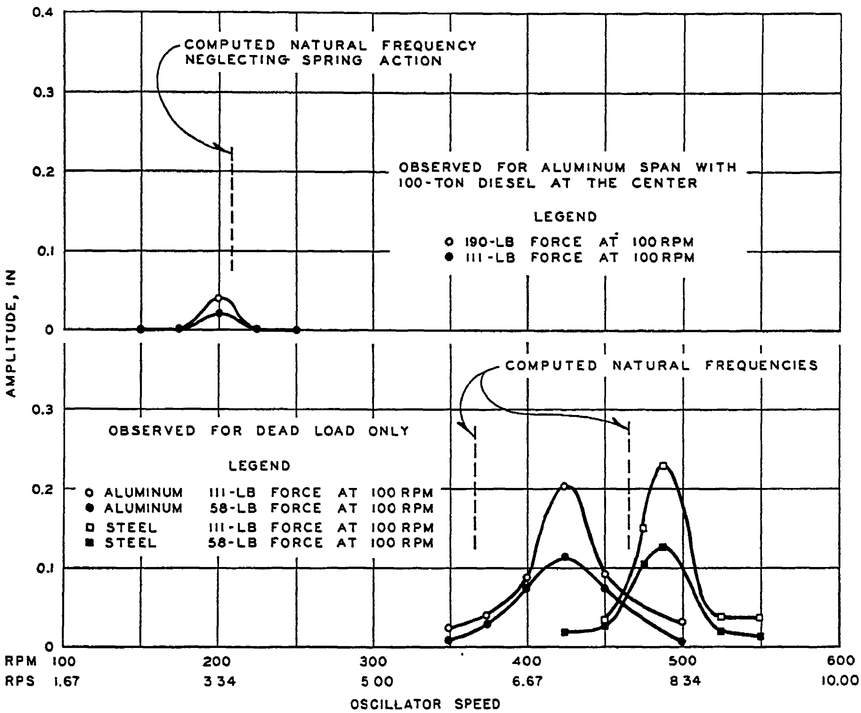


Fig. 11.—Amplitude-Frequency Curves from Vibration Tests—Grasse River Bridge.

If the above formula for determining natural frequnecies is correct, it must be assumed that the dead-load deflections were less than computed by amounts ranging from about 10 percent for the steel girders to 26 percent for the aluminum girders. Some discrepancy between measured and computed dead-load deflections for the aluminum span is not surprising in view of the observations made in the live-load tests.

It will be noted in Fig. 11 that the maximum amplitudes of vibration produced on the steel span were slightly greater than those produced on the aluminum span for the same weights on the oscillator arm, rotating at a speed only about 15 percent greater. This difference in the response of the aluminum and steel spans to forced vibrations may be expressed quantitatively in terms of a "dynamic magnifier." This value is simply the ratio of the amplitude of vibration produced by an oscillating force to the amplitude produced by the same force applied statically. The two curves shown in Fig. 11 for the unloaded aluminum span indicate dynamic magnifiers at the natural frequency averaging 10.7. The corresponding average dynamic magnifier for the unloaded steel span was 25.4. In both cases the variations of the individual determinations from the average were only about 3 percent.

Reference 6 shows that the damping constant for a given span may be determined from the relation:

$$p = \frac{1}{2Kf} \qquad \text{Equation (2)}$$

where p = damping constant,
K = dynamic magnifier at natural frequency, and
f = natural frequency in cycles per second.

TABLE 2.—MEASURED STRESSES AND DEFLECTIONS IN GIRDERS OF GRASSE RIVER BRIDGE UNDER MOVING LOADS AND COMPARISONS WITH STATIC VALUES

Span	*Run No*	*Speed, mph.*	*Maximum Deflection, in.*	*Increase Over Static Value, percent*	*Maximum Stress, psi*	*Increase Over Static Value, percent*
Aluminum	1	12.0	1.53	0	-----------	-----------
	2	27.7	1.71	12	-----------	-----------
	3	29.9	1.74	14	7900	16
	4	31.1	1.70	11	7800	14
	5	31.1	1.70	11	7900	16
	6	32.9	1.70	11	7600	12
				Avg. 12		Avg. 15
Steel	1	28.4	0.69	13	-----------	-----------
	2	31.1	0.69	13	6400	3
	3	28.4	0.65	7	7100	15
	4	33.9	0.69	13	7300	17
	5	33.9	0.69	13	7800	26
				Avg. 12		Avg. 15

Static stresses and deflections used for above comparisons are given in Fig. 5.
Stresses are average for three gages located on bottom cover plates.

tially the same as observed for the steel. It appears from Table 2, summarizing the results of these tests, that the maximum stresses and deflections under moving loads averaged only 12 to 15 percent more than the corresponding maximum static values. The only records showing a significant variation from these average increases were those indicating stresses in the steel girder and here the measured strains were so small that a greater spread in ratios was not surprising. It is of interest to point out in connection with the relatively low impact effects observed in these tests that the maximum increase over the static live-load values assumed in the design of the aluminum girders was 55.5 percent.

Vibration Tests

The natural frequencies of vibration and the damping characteristics of the test spans were of interest because of the bearing these properties have upon tendencies toward resonance under moving loads. It seems quite evident from the behavior indicated in Figs. 8, 9 and 10, however, that resonance was not obtained in these tests. The increment of dynamic strains and deflections produced as the locomotive moved across the span seemed to be about a constant percentage of the mean values.

Fig. 11 shows the amplitude-frequency curves plotted from the results shown in the deflectometer records. The curves for the unloaded spans are of greatest interest because they indicate most clearly the natural frequencies of the two spans and provide a basis for determining the damping characteristics of each. One significant point noted was that the observed natural frequencies exceeded those computed in both cases. The increase for the steel span was about 5 percent, while that for the aluminum span was 16 percent. These computed natural frequencies were determined from the following relation.[4]

$$f = \sqrt{\frac{12.4}{D}} \quad \text{.......... Equation (1)}$$

where f = frequency in cycles per second, and
D = computed dead-load deflection in inches.

the scope of current engineering practice. These tests, made after the bridge had been in service for approximately one year, have carried the demonstration of the possibilities of structural aluminum still further in showing that the behavior of the aluminum girders was in good agreement generally with that computed and that the action was equally as determinate as that of the steel girders of the same bridge. Such observations are of particular interest because they are based on tests of the largest aluminum girders ever built and the first to be used in a railway bridge. The weights of the aluminum and steel spans, exclusive of track and ties, were 53,000 lb. and 128,000 lb., respectively.

Although the bridge was designed for Cooper E 60 loading, these tests were limited to an investigation of stresses and deflections under a single 228-ton steam locomotive, capable of producing maximum static bending moments equal to about 75 percent of the design live-load values. Since the maximum stresses and deflections measured under moving loads on both the aluminum and steel spans were only 12 to 15 percent greater than the static values, whereas an allowance of 55.5 percent had been made for impact in the design of the aluminum span, the test loadings fell considerably short of developing the full live-load working range of the girders. However, the test loadings did exceed by a considerable margin the loads produced by regular traffic over the bridge. The most significant results of these tests may be summarized as follows:

1. The primary bending stresses measured in the static tests (Figs. 5 and 6) indicated a very close similarity in the action of the aluminum and steel girders. The stresses in the cover plates and in the outstanding leg of the flange angles ranged from 1 to 11 percent less than the gross computed values; the average difference for the aluminum flanges being 8 percent, that for the steel flanges being 6 percent. The measurement of stresses generally less than computed suggests that the lateral bracing systems participated in the bending action. It appears from the close agreement otbained between measured stresses in the tension and compression flanges of both girders that at low stress levels, at least, the effect of rivet holes on stress distribution is quite localized.

2. The measured vertical deflection of the aluminum girder under static load (Fig. 5) was about 10 percent less than the computed value, whereas the deflection of the steel girder was about 5 percent less than the computed value. This difference in action may be attributed largely, it is believed, to the overall stiffening effect of numerous splices in the web and flanges of the aluminum girder, which were not used on the steel girder, and to the effect of the relatively much stiffer lateral bracing systems, compared to the flanges, that were used in the aluminum girders. At the center of the spans, for example, the steel girder had about 62 percent more area in the flanges than did the aluminum girder.

3. The transverse strains measured in the fillets of the inside top flanges of the girders under static wheel-load concentrations (Fig. 7) indicated slightly higher stresses in the steel than in the aluminum girder. In neither case, however, did the magnitude appear significant from the standpoint of design.

4. The primary tensile stresses and the vertical deflections measured for both girders under moving loads at speeds of 28 to 34 mph. (Figs. 8, 9 and 10) were only 12 to 15 percent higher than the corresponding static values. No tendencies toward resonance under the hammer blows of the unbalanced locomotive drivers were observed.

5. The natural frequencies of vibration observed for the unloaded spans were higher than computed, the difference for the aluminum being about 16 percent, that for the steel being about 5 percent (Fig. 11). These results reflect not only the increase in the stiffness of the aluminum girder, attributed to the effect of splice plates and lateral bracing, but indicate that the actual weights of both finished structures, complete with track, were less than the values assumed in design.

The natural frequencies of vibration and the dynamic magnifiers indicated by these tests correspond to computed damping constants of 0.0066 and 0.0024 for the aluminum and steel spans, respectively. It appears, therefore, that for any given amplitude and frequency the damping forces or energy dissipation under forced vibrations were greater in the aluminum than in the steel span in the ratio of about 2.75 to 1. This greater damping capacity of the aluminum span may be attributed partly, at least, to the larger number of splices used in the aluminum span.

The vibration tests made with the 100-ton diesel locomotive at the center of the spans resulted in only one well-defined natural frequency and that was observed for the aluminum span at an oscillator speed of 3.33 rps. A bridge span loaded with a series of sprung weights distributed along its length is, of course, a more complex system from the standpoint of vibration analysis than a span under its own weight. The natural frequencies computed for the aluminum span according to the methods of Reference 6, to include spring action, were not at all comparable to the observed frequency of 3.33 rps. The latter value, however, was within a few percent of that computed by Equation (1), neglecting spring action and assuming the locomotive weight to be additional dead load. A similar computation for the loaded steel span indicated a natural frequency of about 4.92 rps. although, as previously noted, no perceptible vibration was observed for this condition at any frequency below 5.83 rps.

Since the moving-load tests previously described indicated maximum stresses and deflections averaging only 12 to 15 percent more than the highest static values, it is of interest to compare the rotational speed of the locomotive drivers with the natural frequencies of the unloaded and loaded test spans. Values for the latter condition were estimated by Equation (1), neglecting spring action.

The locomotive speeds attained over the aluminum span corresponded to rotational speeds of the drivers of from 2.46 to 2.92 rps. During the time required for the locomotive to reach the position producing the maximum deflection the natural frequency of the span varied from about 7.08 cycles per second, as observed for the unloaded condition, to 2.63 cycles per second, estimated for a live-load deflection of 1.53 in. From these data it appears that even at the highest locomotive speeds probably not more than one or two driver impulses or hammer blows were delivered at a frequency matching the estimated natural frequency of the loaded span. It is not surprising, therefore, that no tendency toward resonance in the aluminum span was observed.

A similar analysis of the action on the steel span shows that the natural frequencies of the girders would be expected to vary from about 8.12 cycles per second, as determined for the unloaded condition, to 3.94 cycles per second under the load producing a live-load deflection of 0.61 in. In these tests on the steel span, however, the rotational speed of the drivers did not exceed 3.00 rps., hence synchronism with the estimated natural frequency of the loaded span was not reached.

One point of interest noted in the vibration tests was that the maximum static deflections of the aluminum and steel girders under the 100-ton diesel locomotive were approximately 0.77 in. and 0.33 in., respectively. The measured value for the aluminum was about 13 percent less than that computed for a combination of shear and flexure whereas the measured value for the steel was in almost exact agreement with that computed. A maximum deflection of 0.80 in. was recorded for the aluminum span in one instance under a moving diesel, hauling a regular freight run from the Massena Works.

Summary and Conclusions

The completion in 1946 of the all-aluminum plate girder span for the Grasse river bridge demonstrated that the design and fabrication of such a structure was well within

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Your committee reports on the following subjects:

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR,
H. E. KIRBY, *Chairman.*

AREA Bulletin 484, December 1949.

A

6. Although perceptible vibrations were produced by the oscillator on both spans loaded with a 100-ton diesel locomotive, a well-defined natural frequency was indicated for the aluminum span only. This frequency corresponded closely to that computed for the loaded span, neglecting the spring action of the locomotive.

7. The superior damping characteristics of the aluminum span are shown by the fact that the amplitudes of vibration produced in the unloaded steel span at the natural frequency were about 25 times those computed for the same oscillator force applied statically, whereas the corresponding amplitudes for the unloaded aluminum span at the natural frequency were only about 11 times the static value. The greater damping capacity of the aluminum span can be attributed partly, at least, to the greater number of splices used.

8. The frequency of the unbalanced driver hammer blows at the highest test speeds may have reached the natural frequency of the loaded aluminum span, although no significant "dynamic magnification" of stresses and deflections was observed. The locomotive speeds over the steel span did not reach a frequency of hammer blows equalling the estimated natural frequency of the loaded span, although the indicated impact effects were as great as observed for the aluminum span.

Acknowledgments

Although the tests described were a project of the Engineering Design Division of the Aluminum Research Laboratories, their accomplishment would not have been possible without the splendid cooperation received from personnel of the Massena Terminal Railroad Company, the Massena Works and the Development Division of the Aluminum Company of America. The assistance of these organizations is gratefully acknowledged.

Details of the test procedure and the designs of special equipment were worked out in the Aluminum Research Laboratories under the direction of R. L. Templin, assistant director of research and chief engineer of tests.

References

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3. Railway Bridge with 100-ft. Aluminum Span, Engineering (London), December 5, 1947.
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5. Description and Analysis of Bridge Impact Tests made on Short Open and Ballasted Deck Steel Bridges under Diesel and Steam Locomotives, AREA Proceedings, Vol. 46, 1945.
6. An Investigation of Bridge Impacts with a Mechanical Oscillator, AREA Proceedings, Vol. 49, 1948.

10. Adequate toilet facilities within or convenient to outfit cars should be provided.

11. A refrigerator or ice box of ample capacity to store perishable food should be provided.

12. Kitchens should be equipped with:

(a) Cooking facilities of adequate size.

(b) A sink of such material that it can be readily kept clean.

(c) A metal container with tight-fitting cover for temporary storage of garbage.

13. Cabinets or cupboards should be installed for the storage of dishes, pots and pans.

14. Covered containers are desirable for coal kept in cars.

Operation

15. Outfit cars should be kept in a clean and sanitary condition, in accordance with recommendations of Committee 13.

16. Location—Outfit cars should be located with regard for the safety, comfort and convenience of the occupants.

17. Supervision—Foremen should see that order is maintained, rules observed, and the camp kept in proper condition.

18. Inspection of outfit cars should be made at stated periods, preferably monthly, to insure the proper physical and sanitary condition of the equipment.

Plans

19. Outfit cars, to meet various conditions and requirements, are of several types and designs, with varying interior arrangements and furnishings. Generally, such cars are adapted from rebuilt box cars, although some types of outfit cars have been adapted from retired passenger train cars and troop sleepers. Following are listed some of the types of outfit cars in general use, the design of which varies with the type and size of gang:

Sleeping car
Combination sleeping and recreation car
Dining car
Kitchen car
Combination kitchen and dining car
Combination kitchen, dining and sleeping car
Foreman car
Combination foreman and sleeping car
Combination foreman and commissary car
Combination foreman and recreation car
Recreation car
Shower car
Laundry car
Combination laundry and shower car
Water and fuel car
Commissary car
Refrigerator and store car
Power car (generator, pump and water tanks, or generator and tools and equipment)

Report on Assignment 1

Revision of Manual

N. D. Howard (chairman, subcommittee), Lem Adams, W. H. Brameld, E. J. Brown, F. G. Campbell, R. J. Gammie, C. G. Grove, Roy Lumpkin, J. S. McBride, G. M. O'Rourke, W. G. Powrie, A. G. Reese, E. C. Vandenburgh, Edw. Wise, Jr, C. R. Wright.

This report is confined to revision of that material in the Manual under "III HOUSING MAINTENANCE OF WAY EMPLOYEES, 1939," pages 22-10—22-14.

Heading

Change heading quoted above to

OUTFIT CARS FOR HOUSING MAINTENANCE OF WAY EMPLOYEES

1950

A. Sanitary Provisions

Withdraw present material under this heading, with the recommendation that all matter relating to sanitary provisions in connection with the housing of maintenance of way employees be assigned to Committee 13—Water Service and Sanitation, with the request that in this matter it collaborate with Committee 22.

B. Plans for Outfit Cars

Delete present heading and all text material under this heading, except the typical plans for outfit cars, and substitute the following:

A. PLANS FOR OUTFIT CARS

1950

The following suggestions are presented as a guide for the design and operation of outfit cars:

Design

1. Cars selected for use as outfit cars should be of such type and construction as to permit handling any place in train.
2. They should be designed and equipped for comfort and for economy in heating.
3. More comfortable living conditions may be justified in cars for gangs employed continually throughout the year than for seasonal gangs.
4. Platform-type steps at the doors of cars are desirable both as a matter of convenience and safety.
5. In providing outfit cars, the standards of living conditions to which the occupants are accustomed, should be taken into consideration.
6. Recreational space, especially for year-around gangs, is desirable. This area will vary with the size of gang. For many gangs, a part of a car may be sufficient or the dining room can be arranged for this purpose.
7. The interior painting or other finish should be such as to facilitate cleaning and sanitation.
8. Good ventilation and comfortable beds are desirable.
9. Electric lights, hot and cold running water, showers, and adequate heating will make outfit car life more attractive and will aid in recruiting desirable men and retaining them in service.

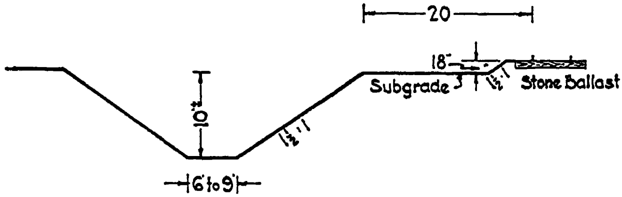

Fig. 1.—Typical Cross Section of Deep Ditching.

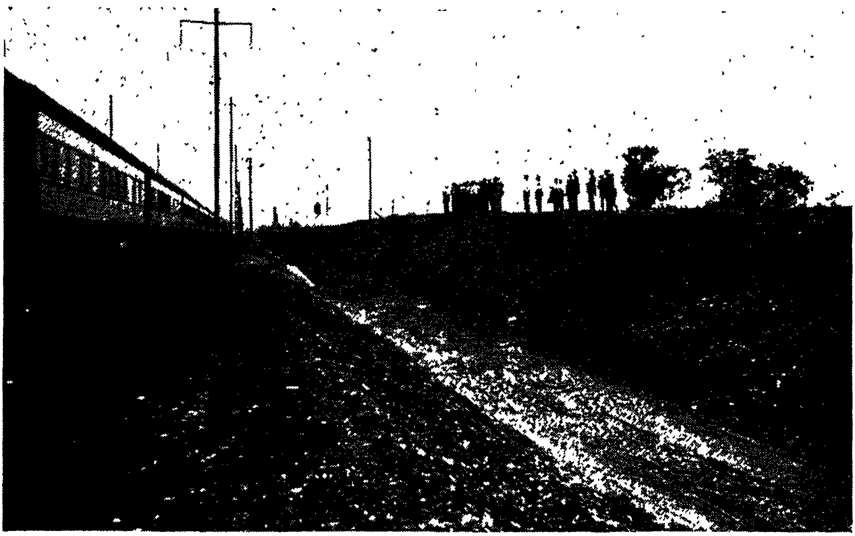

Fig. 2.—Typical Deep Ditching.

Economy:

Cost not expected to exceed 75 percent or 80 percent of the amount necessary to do the work by contract. In addition, there is a resulting decrease in track maintenance. The roadway which is formed at the top of the ditch provides additional savings in the ease with which men and material can be transported alongside the right-of-way.

2. Deep Ditch Cleaning:

Equipment:

One Gradall machine manned by two men.

Two 5-ton capacity dump trucks.

Production:

Ditch cleaned per day 500 ft. to 700 ft.

Costs:

One Gradall machine, approximately $26,000.

Economy:

The average cost of ditch cleaning per foot, including depreciation, interest, etc. is 12 cents. This is considerably less than ordinary costs. Together with

The following drawings, Figs. 2201 and 2202, show typical plans for the construction and arrangement of:

Foreman car
Kitchen and dining car
Sleeping car
Water and fuel car
Recreation car

for use in maintenance of way work, using either freight or passenger equipment. It is recommended that living conditions of outfit cars be made as comfortable and sanitary, in accordance with these general plans, as economic considerations permit.

Drawings

Retain drawings of outfit cars—M. W. Department Outfit Cars, pages 22–13 and 22–14. Subsequent consideration will be given to revising these plans.

Report on Assignment 2

Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

C. W. Reeve (chairman, subcommittee), H. C. Archibald, E. J. Brown, F. G. Camnbell, J. P. Ensign, R. J. Gammie, N. D. Howard, G. A. Kellow, H. E. Kirby, E. H. McIlheran, H. L. Miller, G. M. O'Rourke, E C. Vandenburgh, J. S. Wearn, Edw. Wise, Jr.

This report is presented as information.

Through the courtesy of the Pennsylvania Railroad, Committee 22 was given the opportunity to make a study of the economies that have been realized by that railroad through the use of mechanized methods of roadway and track maintenance on that property.

The following projects were observed and studied by the members of the committee:

1. Deep Ditching:

   Depth: Seven to nine feet.

   Equipment:

   One ¾-yd. dragline bucket and crane.
   One 100-hp. tractor with angle dozer and winch.
   One Gradall machine.
   Two 5-ton capacity dump trucks.
   One 160-cu. ft. air compressor with demolition tools.

   Extent of work:

   One mile of deep ditch 7 to 9 ft. in depth, creating a track shoulder 20 ft. in width.

   Material handled:

   25,000 yd. of earth and shale, and the relocation of 23 sets of catenary pole guy wire anchors.

Fig. 5.—Dirt Wasting Trestle.

Fig. 6.—Pennsylvania Railroad Track Sweeping Machine.

Fig. 3.—Deep Ditch Cleaning.

Fig. 4.—Self-Contained Train-Mounted Ballast Cleaning Machinery.

2. Brooms and plow for snow removal.
3. Sickle bar for mowing right-of-way.
4. Front-end loader for handling material from ground to cars and trucks.

6. Rail Laying Train:

Equipment:

Spike pullers
Power wrenches—unbolting
Ballast extruders
Adzers
Rail laying crane
Rail end greaser (designed by the Pennsylvania)
Rail joint clamp
Power wrenches—bolting
Power tie borer—boring for hold-down spikes
Pneumatic spike drivers

In addition to the above equipment, several small tool adaptations made the rail laying work more efficient. Picks with one point removed had been adapted to facilitate the removal of old plates from the ties. Specially built tools were used for driving down the tie plugs. These were made of a flat weight affixed to a handle. Tie tongs had been converted into a tool for picking up new tie plates off the shoulder and laying them in place on the ties after adzing and painting them with creosote. A steel rod gage was being used by men placing new rail on the tie plates.

Economy:

The economy of mechanized rail laying has long been proved. The quality of rail laying achieved with mechanized equipment is superior to that of hand work. The rail train organization is considered as a regional unit, is housed in camp cars, and moved from one location to another, circus fashion, as the rail removal program progresses.

Considerable economy has been effected by having the train carrying the rail laying equipment from point to point equipped with ramps and loading devices, so that the rail laying equipment may be very readily loaded and unloaded.

7. Ballast Cleaning by On-Track Ballast Cleaning Machinery:

Equipment:

Self-Contained Train-Mounted Ballast Cleaner. This machine cleans the ballast only on one side at a time, and averages a cut of ten inches below the bottom of the ties.

Cost:

Initial cost of machine and appurtenances $450,000.

Production:

Per working hour 1400 to 1600 lin. ft. of intertrack space. This machine works 24 hours per day. The average daily production is 20,000 lin. ft. of intertrack space or shoulder.

Cost of cleaning:

Average cost seven cents per track foot of intertrack space or shoulder.

Economy:

The cost of ballast cleaning with this machine is not only less than the cost of cleaning by hand work, but the speed of cleaning results in considerable economy.

the small cost of ditch cleaning, the quality of the work produced is extremely high.

The Gradall machine is versatile. In addition to its use for deep ditch cleaning, it can be used for digging and backfilling trenches necessary for the repair and installation of pipe lines. It can also be effectively used to load materials from ground to railroad cars, and can be used for snow handling with a specially designed snow handling bucket.

3. Pneumatic Tamping: Out of face

Equipment:

Pneumatic tamping tools—24

One 315-cu. ft. capacity crawler air compressor

Costs:

Compressor, pneumatic tools, hose, etc. $13,000.

Rate of tamping:

Per working hour 150 lin. ft. to 180 lin. ft. under very heavy traffic and with no interruption to train speeds by maintaining a constant run-off.

Economy:

With a ten percent saving in man hours this type of tamping is expected to last twice as long as that done by hand tamping with picks. By the use of a portable air compressor moving with the progress of the work no long pipe lines nor compressor set-offs are required, with resulting economy.

4. Ballast Cleaning with Moles:

Scope of Work:

The cleaning of intertrack or border ballast at locations where density of traffic or physical characteristics will not permit use of larger "on track" ballast cleaning equipment.

Cost of cleaning:

Average cost of ballast cleaning 17.3 cents per foot.

Economy:

Using moles on a double or two 8-hour tricks per day basis, 14,400 less man-hours are required than by performing the same amount of cleaning by use of hand tools. This saving of man-hours was accomplished in 1948 while cleaning 508 miles of intertrack and border ballast.

5. Pneumatic Spot Tamping:

Equipment:

One air compressor—105-cu. ft. capacity

Six pneumatic tamping tools

Detail of air compressor:

Some mounted on two-wheel pneumatic tired chassis equipped with hitches for touring. Some, which are the more popular, are an integral part of a pneumatic tired farm type tractor.

Cost of Air Compressors:

Two-wheeled type, about $1950 to $2500.

Tractor type, $2700 to $3200.

Advantages:

The tractor type of air compressor is a valuable asset in the possession of section gangs because of its adaptability. This type of machine is still more valuable when equipped with:

1. Trailer for hauling men, tools and material.

11. Track Sweeping:

Machinery:

Diesel power track sweeper built by the Pennsylvania.

Cost:

Approximately $380,000.

Scope of the Work:

Cleaning tracks of cinders, sand, and coal.

Production:

Working two tricks eight hours each per day during 1948 this machine cleaned 745 miles of track, loading 750 hopper cars of dirt.

Economy:

Under normal conditions this machine can load a car of dirt from between the rails every 40 min. of working time.

The Pennsylvania has made a very thorough study of the economies to be gained through the use of mechanized maintenance of way methods. Through the use of machinery some of the savings are particularly high as shown by the table.

Summary of Economies Realized

Machine	*Days Worked Each Year*	*Daily Output of Machine*	*Man-hours Saved Annually, each Machine*
Portable power wrench	275	1,200 nuts	6,600
Rail drill	75	60 holes	1,800
Spike puller	200	13,200 spikes	11,200
Tie adzer	200	1,320 ties	12,800
Burro crane	250	Varied	22,000
Air spike drivers (1 compressor and 4 hammers)	200	17,400 spikes	36,800
Oxyacetylene cutting outfit	100	Varied	7,200
12 Tool air tamper incl. compressor	225	700 ft. track tamped	4,492
Portable electric tamper—6 tool	125	300 ft. track tamped	916
Portable gasoline driven unit tie tamper	125	Varied	500
Gasoline crawler crane	250	Varied	30,000
Power jack	200	"	19,200
Auto truck crane	200	"	12,800
Mole ballast cleaner	200	800 ft. border ballast	4,800
Mole ballast cleaner	200	600 ft. border ballast	11,200
Brown hoist ballast cleaning machine (24 hrs. a day)	188	15,000 ft. inter-track space	487,296
Rail saw	75	24 cuts	1,200
Paint spraying outfit (4 guns)	150	Varied	2,400
Chain saw	100	"	4,800
Pumpcrete machine	100	"	17,600
Concrete mixer	150	"	14,400
Jack hammer	100	"	12,000

It has been found through the study of the use of this work equipment that a saving of 3560 man-hours has been effected for each $1000 invested in mechanized maintenance of way equipment.

8. Wasting of Dirt Removed by Ballast Cleaners:

While not in itself a work equipment project, it has been necessitated by mechanical ballast cleaning and sweeping operations. A 700-ft. trestle constructed of piles and timbers is used for dirt disposal.

Cost: $16,000,

Capacity:

Sixteen cars can be unloaded at one time.

Total dumping capacity available—400,000 cu. yd.

Economy:

By use of this trestle type dumping facility 195,000 cu. yd. have been unloaded at a cost of 13 cents per yard.

Note: Dirt unloaded from this trestle is constantly levelled and compacted by means of a crawler bulldozer. The location of this trestle was purposely chosen at a point where considerable bank widening is required, resulting in the installation of needed additional embankment from material the disposal of which is essential.

9. Grading for Realinement of Tracks:

Project:

Change of alinement to permit reducing an 8-deg. 30-min. curve 1135 ft. long to a 6-deg. curve.

Extent:

Excavation of 22,450 cu. yd. to make the required fill. Its construction will provide a dumping place for approximately 130,000 cu. yd. of material requiring wasting.

Equipment:

One 15-ton crawler crane with 1½-cu. yd. clamshell bucket.

Production:

One crane operator and two laborers employed on each of two 8-hour tricks per day unload 12 cars per day.

Economy:

To date 21,000 cu. yd. of fill has been placed at an average cost of 27 cents per yard. This filling material is waste material, resulting in additional economies.

10. Complete Track Rehabilitation:

Project:

Raise track, renew ties, reballast, retamp, and cross grind overflowed metal from rail ends.

Equipment:

Power track jack

Power ballaster

Power wrenches

Cross-grinder equipped with unbreakable wheel. Tie lifter, incorporating a conventional track-mounted air compressor, to which has been added a device for picking up and holding ties against base of rail while air furnished by compressor is used to operate spike drivers.

Economy:

By the use of this machinery and by diverting traffic it is possible to rehabilitate one-half mile of track per day, using an organization of from 75 to 125 men, depending on the extent of tie renewals.

A most important factor in the use of the power ballaster is the unloading and distribution of ballast. The manner of its distribution will largely determine the progress of the machine, the quality of the work, and the economy of the whole job. Too much or too little ballast is of about equal disadvantage. Both conditions require that men be taken from regular duties to fork the excess from the track, or to equalize the available quantity. As ballaster tamping is somewhat in the nature of an industrial assembly line, such interruptions completely disrupt the sequence of operations. The best means for unloading and distributing ballast is the use of cars designed specifically for that purpose. If such cars are not available, however, there are devices adapted for use with hopper cars which give reasonably satisfactory service. But it is extremely difficult, when not using cars specifically designed for the purpose, to distribute ballast precisely as needed. Varying conditions of track, and the design of the machine are contributing factors. On double-track territory, more ballast usually is needed on the outside than in the intertrack space. This problem is not encountered on inside tracks in multiple-track territory, unless the outside tracks are unusually lower than the adjacent tracks. Grade stakes, visible from both sides of the work train, are of substantial aid in the unloading operation. This phase of the work requires constant, competent supervision.

Requirements for Jacking

A hydraulic power track jack is used in raising the track. This jack is used some distance in advance of the machine, the foot being placed in the crib between the end joint tie and the next tie, in which position it is moved along progressively. After the track has been raised, the usual practice is to bring the surface of the rails to a true plane by removing surface irregularities. This is accompanied by using small track jacks and level board. Small jacks having a relatively large foot, designed for use under ties, possess advantage in this operation. This work is performed between the power jack and the ballaster. Best results are obtained with an equal and uniform lift of both rails. Where it is necessary to change the superelevation of curves, such change should be made in advance of the power ballaster lift.

Under one method of tamping, the small jacks are placed under the ends of every sixth tie and are moved forward at regular intervals as the work proceeds. In this manner the jacks function also as track stabilizers. Another method, found to possess important advantage, is to fork tamp the quarter ties on the ends after the track has been brought to level. This provides additional support to the rails, thus minimizing deflection under the weight of the ballaster. Such support has an advantage over the use of small jacks only in that greater bearing area is provided, which is of definite value on double track at locations where bearing ratios vary with the relative compressive strength of materials under the inside and outside jacks.

Supplying Ballast Where It Is Needed

As the ballaster progresses it is of great importance that ballast be supplied to cribs at the right time and in the correct amount. As it is virtually impossible to unload ballast, by whatever means employed, in precisely the correct quantities at all points where needed, it is necessary to assign men the task of equalizing this material. Accordingly, it is desirable that all ballast required for the inside tamping bars be in that space prior to tamping. In tamping the space outside the rails, it has been found that best results follow the practice of keeping the ballast at a level of about two inches above the bottom of the ties. This feeding of ballast is usually assigned to four men, two outside each rail at the machine, or, with ballasters of most recent design, two men are sufficient for this purpose. Their function is quite important, since failure to provide

Conclusion

Very important economies are being effected by the use of mechanized track and roadway maintenance equipment. The use of work equipment is carefully planned and work schedules established in advance. Maintenance of work equipment follows a definite program. Particular attention is given to using the correct machine on the project for which the machine is best fitted.

Report on Assignment 3

Organization of Forces for Track Maintenance Operations

H. E. Kirby (chairman, subcommittee), Lem Adams, H. C. Archibald, E. J. Bayer, H. W. Flemming, E. A. Gill, K. H. Hanger, K. E. Henderson, W. I. King, W. H. Miesse, W. G. Powrie, W. H. Vance, G. E. Warfel, H. J. Weccheider, J. G. West, Jr., C. R. Wright.

At intervals over a period of years, under this and closely related assignments, your committee has made several studies of methods, practices and force organizations used in various track maintenance operations. The present study is concerned with the organization used with a highly specialized machine—the power ballaster. It is presented as information.

The power ballaster is a self-propelled, on-track, machine designed to tamp ballast under ties of track raised out of face. This machine twice has been described by Committee 27; the results of its study appear in Procedings, Vol. 45 and Vol. 49. It is sufficient here to state that the power ballaster is designed for the single purpose of tamping ballast under the ties, and that the machine satisfactorily performs this function, providing the track has been properly prepared in advance. Both sides of a tie are tamped simultaneously, the action of the tamping bars describing an arc inward at the bottom of the vertical stroke.

Conditions To Be Met in Advance

Modern standards of operation and necessity for economy require observance of certain practices of preliminary track preparation. Most of these factors are essential to good maintenance under any system of tamping; others are indicated by the method under study. A thorough inspection of the track should be made well in advance of preparing tamping programs and work schedules. Varying conditions of ballast, ties and other materials require different treatment. Tie renewals may be such that a prior raise is necessary for economical installation and spacing. It is believed that better maintenance and operation will result on most properties from the setting of line and grade stakes. The new grade should thus be established in advance of any tie renewal or spacing operations, during which any low spots may be removed. A final uniform lift is thereby left for power ballaster tamping, and the track should be in readiness for the use of that machine. Proper tamping requires that the track be raised to a height which will provide space under the ties sufficient to pemit entry of the largest size of ballast used. To take full advantage of the tamper action, the material in the cribs should be sufficiently loose to allow the tamping bars to complete the arc at the bottom of the downward movement. Track with fouled ballast should be stripped or cleaned prior to the tamping operation. It has been found, in general, that a minimum lift of 2½ in. is required to tamp newly spaced track, and that the raise must be greater for track having a more solidified ballast.

The foregoing is based upon the principle of continuous operation. This practice contemplates performance of the same part of the work every day by each man or group of men.

While the importance of ballast unloading and distribution is emphasized in paragraph four, it will be noted that detailed study is not given the operations of ballast handling and dressing. It was felt that to attempt uniform treatment and definite recommendation in this regard would be impracticable in view of the variation in types of cars, equipment and ballast used.

Restoring ballast to standard cross section should follow the ballasting by at least two days in order to give the track time to settle under traffic.

Report on Assignment 6

Labor Economies of Various Types of Foundations Under Railroad Crossings

J. B. Clark (chairman, subcommittee), M. B. Allen, B. L. Beier, W. H. Brameld, R. H. Carpenter, G. E. Chambers, C. G. Grove, K. H. Hanger, K. E. Henderson, J. E. Inman, W. I. King, Roy Lumpkin, H. C. Minteer, W. G. Pfohl, A. G. Reese, J. D. Taylor.

This is a progress report submitted as information.

Proper maintenance of railroad crossings is important both from the standpoint of safety and economy. One of the strongest factors affecting the cost of maintenance of a crossing is its foundation.

A questionnaire was addressed to maintenance officers of 30 railroads, asking for detailed information showing comparison of cost of maintenance at crossings where the type of foundation was changed. A reply was received from 20 of these railroads. In many cases these roads were not in a position to give any actual statistics, due to the fact that they had not kept a record of the cost of maintaining the crossing before the type of foundation was changed. In many cases the weight of rail, or the design of the crossing itself, was changed at the time the foundation was changed. It was, therefore, necessary to develop this report from a relatively small number of replies.

For the purpose of this assignment, the foundation is considered as everything below the base of rail in the crossing. Good drainage, and ballast that is easily worked under the supporting timbers, giving them a uniform support throughout, are items beneficial to crossing foundations the same as to the foundation of any track structure.

One road reports important labor economies obtained by using small ballast (¼-in. to ¾-in. crushed limestone or slag) filled in to a depth of only an inch or so above the bottom of the crossing timbers. The principal reason for the relatively light filling of small ballast, as practiced by this road, is the fact that it accelerates evaporation, and provides a means of quick drying after rains. This method is reported as being highly effective in thus improving drainage and in reducing the amount of labor required in minor surfacing jobs.

In an attempt to improve crossing foundations. the following special features have been tried at various locations:

1. Tie pads.
2. Through timber supports instead of cross timbers.
3. Concrete slabs under 12 to 18 in. of ballast.
4. Pressure grouted subgrade.
5. Pipe drainage,

sufficient ballast at that time will result in uneven settlement and in the waste of much preparatory work. These men are trained to throw the correct quantity of ballast into the crib during the upward motion of the tamping feet and before the operator has completed the entire series of the six strokes which will tamp a tie under average lift. Four strokes usually are sufficient for the ties which have been fork tamped in advance of the ballaster, and those ties should be marked or identified for the operator. In preparing run-offs, approximately half of a temporary run-off can be tamped with the ballaster, the number of its strokes being limited to those which are effective. When no further ballast can be put under the tie after the fourth stroke, the machine should be stopped and the remainder of the run-off tamped by other means.

Ties at insulated joints should be marked in order that the ballaster operator will avoid striking any of the facilities involved. The ties thus skipped should be fork tamped at once on eight faces. To provide approximately equal settlement, the same ties should be brought up to surface as soon as possible with a mechanical tamper.

Other Work To Be Done

Following the ballaster machine, it is necessary to reset and replace rail anchors, tap down spikes, tighten bolts loosened ahead of the raising, rough dress the track, and gather tools.

The track should, by all means, be lined the same day it is raised, and before it is turned over to traffic. A competent force with no other duties, usually can line all of the track worked during the day by the ballaster. In the morning, while the ballaster gang is getting started, the lining gang can be taking out any kinks which developed overnight in the previous day's work and can then follow the ballaster with the current day's lining. It is recommended that the first train operating over newly tamped track be restricted to 30 mph.

A power broom may be operated between the ballaster and the lining gang to remove ballast from the tops of ties.

The following basic organization is offered for the operation of a single ballaster under average conditions:

1 General foreman
1 Watchman, with hand siren
1 Water carrier
1 Handling expansion
2 Preparing holes for small jacks in advance
1 Power jack operator
1 Handling level board
2 Setting jacks at power jack
2 Setting jacks at quarters
1 Foreman—raising track
1 Assistant foreman—spotting opposite rail
6 Equalizing ballast
1 Power ballaster operator
4 Feeding ballast to cribs (Max. of 2 required with machines equipped with automatic feeders)
1 Foreman—ballast feeding and tamping
1 Mechanic
2 Removing small jacks
4 Carrying small jacks
2 Tightening bolts
1 Sweeping
1 Foreman—lining track
12 Lining track
1 Assistant foreman—spot tamping, rough dressing
2 Replacing and adjusting anchors, tapping spikes, etc.
2 Operating spot tampers—ties skipped, etc.

Supervision

General foreman	1
Foremen	3
Assistant foremen	2

Personnel

Mechanic	1
Machine operators	2
Laborers	45

In addition to the laborers listed, operations may require the use of flagmen as necessary under local conditions.

Application of 40-Hour Week Agreement

Except for relief assignments, all roads are working their forces Monday through Friday. This is being done without exception on 38 roads, and on 26 roads some modifications have been made for part of the force.

Relief men have generally been used for crossing watchmen, pumpers, bridge tenders, sometimes track patrolmen, etc., working on seven-day assignments. Generally a section laborer is used for relief on Saturdays and Sundays and works on a section three other days in the week except that for bridge tenders some roads use a bridge man for relief.

A western road, which is now working its forces Mondays through Fridays, is still negotiating with the employees' organization, and in all probability will be able to reach an agreement which will permit approximately eight percent of its sections to work Tuesdays through Saturdays. These sections will be in mountain territory where emergencies may frequently arise; also in terminals, especially those in which relief outfits are maintained so that the gang would be available to accompany the relief outfit in the event of emergencies.

Four roads advise it may be found necessary to stagger work especially in terminals and yards during winter, periods of snow, or if operational necessity develops, and one of them has made definite arrangements to do so.

One eastern road reports that developments may require variation in the working days of its signal forces.

A southern road advises its intention to work Mondays through Fridays and has no plan to do otherwise, but has held to the right to stagger any and all forces as may be necessary to meet operational requirements as permitted under the Chicago agreement. The organization took exception to this stand and the matter is under consideration by the 40-Hour Week Committee.

Two roads state that they attempted to stagger the work week but that the organization would not agree and one of them has put the matter up to the 40-Hour Week Committee.

Of the 26 roads reporting that have made some modifications in the Monday through Friday work week, all but six of them apply the modifications only to terminal and yard territories, and on five of them the modifications are limited to certain periods of time.

On one road the modification applies only in cases of emergencies and on another the only exception is one man who takes care of switch lamps Tuesdays to Saturdays, on a third road the only exception applies to track patrols on Tuesdays through Saturdays.

One road that is staggering its forces in yards and terminals wants the right to stagger all forces and now has the matter up with the 40-Hour Week Committee.

A southern road has the right to stagger forces at terminals where two or more gangs are employed, but is going to try to get along without doing so. If all section forces on a terminal have the same rest day, their agreement permits them to hold half of the force, from alternate sections, subject to call.

A western road has signal maintainers working staggered assignments; monthly rated telegraph maintainers are assigned six days per week. They want to stagger certain section forces and the matter is now up to the 40-Hour Week Committee.

On a northwestern road certain section forces must be on duty seven days a week at stock yards and ice houses. In such cases, where crews are large enough, they are rotated so that some of the crew is always on duty for seven days a week, and one man in the gang is promoted to foreman to work the sixth and seventh days. This road also has the alternate of working Saturdays, and accumulating rest periods, but this is done only where absolutely necessary.

Tie pads placed between the plates and ties have proved beneficial in some installations by prolonging the life of the crossing frogs. It is reported that the labor of maintaining crossings has been reduced as much as 25 percent by the installation of tie pads at specific locations.

Through timber supports have been used in place of the conventional cross timbers. These have been satisfactory where the timbers were treated hardwood, framed carefully before being treated, and securely fastened together, giving a support under each rail running in the same direction as the rail. Good drainage is essential to this type of construction, particularly because of the tendency of water to gather inside the box-type support. Reports were received stating that where this type of installation was made the labor used in surfacing the crossing was reduced by 33 percent, the life of the crossing was increased by 66 percent, and the period before the first welding was necessary was increased 150 percent.

In all cases reported, where concrete slabs from 15 to 24 in. thick were placed under 12 to 18 in. of ballast, the labor used for maintaining the crossing was reduced. Savings in labor up to 75 percent were reported where concrete slabs were installed.

Pressure grouting of the subgrade under railroad crossings has been widely used, and in all cases reported, has reduced the labor required for maintaining the crossing. The reported savings in labor where the subgrade was grouted ranged from 10 to 75 percent.

Pipe drainage is effective at crossings where the maintenance expenditure is heavy because of poor natural drainage. Savings in labor up to 33 percent have been reported where pipe drainage has been installed.

Conclusions

Labor economies can be realized in the maintenance of railroad crossings by improving the foundation at locations where the labor necessary to maintain the crossings is excessive.

If experience shows that the labor required to maintain a crossing is excessive, the improvement of surface drainage or the installation of tie pads, through timber supports, concrete slabs, pressure grouted subgrade, pipe drainage, or a combination of two or more of these special features should be considered, weighing estimated saving in maintenance against the cost of installation.

Report on Assignment 8

Meeting the Conditions Imposed by Shorter Work Week

J. S. McBride (chairman, subcommittee), G. A. Kellow (vice-chairman), Lem Adams, E. J. Brown, F. G. Campbell, H. W. Flemming, R. J. Gammie, C. G. Grove, K. H. Hanger, N. D. Howard, J. E. Inman, G. M. O'Rourke, E. C. Vandenburgh.

This is a progress report submitted as information.

In handling this assignment, your committee has endeavored to ascertain the application of the 40-hour week agreement in the maintenance of way department and what steps have been taken, will be taken, or are considered necessary to offset the increased costs of the shorter work week. Replies to the committee's inquiry were received from 64 railroads operating approximately 226,000 miles of road.

One road that is not increasing its supervisory force considers it highly probable, because of business conditions, that it may have to reduce forces, and two other roads report that any increase in supervision in the future will have to be studied and developed, and will depend upon the results obtained from the shorter week. Some of the plans to secure more intensive supervision include the educating of supervisors to more aggressive functioning and to the necessity of closer supervision; closer work by division and assistant engineers with supervisors to see that only essential work is done, and as well as to have material on hand to avoid all unnecessary delays; and more frequent meetings of all supervisory forces in the division engineer's office. One plan is to standardize work on all divisions to most economical methods and to have supervisors follow up work closely to see that the standard methods adopted are being followed.

One road made a slight increase in its supervisory force; two others did so by reducing the length of the roadmaster's district, one to an average 100 miles, another to 130 miles. Several roads added assistant roadmasters or assistant supervisors without stating the number, and two added one supervisor. On one road the increase was 50 percent.

A southwestern road increased its roadmasters by 50 percent in order to provide the supervision it considers necessary under the 5-day week. It does not plan to increase the supervision of bridge, building and signal work.

A midwestern road has added assistant supervisors in the track department to exercise closer supervision over individual section gangs daily. Its bridge and building force is continuing its same supervision, excepting that one man has been added in the field to do some engineering work formerly expected of bridge and building supervisors, and generally provide relief to them in this respect.

One northwestern road feels so strongly that more intensive supervision is necessary that it not only retained all of its bridge and building supervisors, as well as its track supervisory forces which consisted of 56 roadmasters and 8 assistant roadmasters, but just prior to September 1, 1949, increased its track supervisory force by the addition of 47 track supervisors reporting directly to the roadmasters and having full supervisory authority over the track forces.

A northern road, to provide additional supervision, appointed a number of track supervisors who will act in the general capacity of assistant roadmasters. The newly appointed track supervisors have been assigned territories varying in length from 41.7 miles to 53.3 miles, each covering his territory completely by himself on a track motor car Mondays to Saturdays, inclusive.

Seven roads volunteered information as to periods they are working their roadmasters and/or supervisors. Four of these roads are working supervisory force only five days per week, except in cases of emergency, and three of them are using such force six days per week. One of the latter roads states it is continuing the practice of allowing supervisors Saturday afternoons off when things are all right, and another has given its supervisors a wage adjustment to compensate them for work beyond the 40-hour period. Some additional information on this subject is shown later under the heading of Patrolling Track.

While about 70 percent of the roads expressed themselves as considering that training of supervisors is desirable to make them better leaders and thinkers in order to increase output, most of the roads make no provision for training their supervisors. A few roads state they are too small to put training programs into effect. Eight roads have training courses for supervisors, and two others are endeavoring to provide such courses. Eighteen of the roads are giving supervisors training on the job, mostly by appointing assistants to roadmasters and supervisors. After a few years these trainees are ready for the responsibility of taking over a territory. In many of these cases young

Of the five roads that are limited as to the time forces can be staggered, three of them are limited to the snow season, winter weather or winter months. The other two are limited by definite days, one from November 1 to April 1, and the other November 15 to March 1.

Forty-six roads are making no exceptions of bridge, building and other floating gangs, while 10 roads are allowing some of their floating gangs to work their 40 hours in less than five full days, so that the men in these gangs may get home over week ends. Five roads are having gangs accumulate rest days; one road works its maintenance floating gangs Tuesdays through Saturdays; two roads did not advise of their practice.

Of the ten roads allowing gangs to make up time, seven of them apply this practice to all floating gangs, two to bridge and building gangs, and one to bridge, building and signal gangs. A few roads apply this exception only in cases of hardship or where train service is such that the men cannot readily get home. Five roads limit the time to be made up to four hours per week, or working a maximum of nine hours per day, one road limits make up to three hours per week, and the other four roads place no restriction on the amount of time to be made up or the maximum number of hours that may be worked in a day.

One northern road states that large extra gangs are not under the agreement and are not affected by the 40-hour week, except foremen and subforemen who bid these jobs from seniority. The foremen and subforemen of these gangs are allowed to accumulate rest days. Bridge and building floating gangs elected by popular vote to take long week ends; for instance, the first week they work Tuesday through Saturday, the second week Monday through Friday, and on that week end are off Saturday, Sunday and Monday, and then alternate as above. Two shops on this road, each employing 10 to 15 men, can if necessary, work two men Tuesdays through Saturdays.

A midwest road is working extra gangs continuously seven days per week at straight time and allowing them to accumulate rest days. The agreement expires at the end of 1949 and can only be continued by mutual agreement. The success of the plan will depend entirely upon whether or not it is found desirable by the employees. The road believes this plan will increase the efficiency of these gangs and avoid the loss of transitory forces during long week ends.

Another midwest road advises that most of its bridge and building gangs elected to work Monday through Friday of each week, but said that a few crews located in territory where train service is such that it is difficult for men to get home, elected to take Saturday, Sunday and Monday every other week as their rest days, and only Sunday in the alternate week end.

A southern road's policy is to work bridge and building forces Mondays through Fridays, except in special cases where the men live on one end of railroad and work on the opposite end. In these special cases some consideration will be given to allowing the men to work sufficient hours to go to their homes every two weeks, making up two days time. The agreement of one midwest road provides that members of bridge and building crews will accumulate rest days.

Supervision

It is the opinion of a majority of the roads reporting that more alert, more intensive and closer supervision will be required to offset in part the increased costs of the shorter work week. Seventy-five percent of the roads reporting do not plan to increase the supervisory force, while 17 percent have already done so or will provide for additional supervisors; 3 roads are considering additional supervisors and 2 have increased supervision by realinement or reassignment of existing forces.

A northern road, to relieve section gangs of patrolling, has appointed track patrol foremen who are assigned Tuesdays through Saturdays. Regular section gangs patrol on Mondays. The patrol foremen have a patrol section of 35 to 50 miles and use light motor cars. On double-track territory they patrol one track the first day, remaining away from headquarters that night, and patrol the other track the next day. Bunkhouse accommodations will be provided for two track patrol foremen where their territories meet, and they will be allowed a definite sum for meals. Where track conditions are normal and block signals are in service the track will not be patrolled on Sundays and holidays. At the present time where Sunday passenger trains are operated and block signals are not in service it is the practice to patrol such territories but there is considerable doubt as to whether this will be continued.

On another northern road, some territories are being patrolled by track supervisors, on motor cars, under roadmasters. On other territories on this road, the method of patrolling has not been changed.

An eastern road has established 2-man patrol crews composed of a track patrol foreman, at a section foreman's rate, and one patrol trackman, at trackman's pay. Tuesdays through Fridays they work as trackmen, or in some cases as section foremen, and on Satudays, they patrol some 40 miles of main line track. If their patrol work is completed within eight hours they go back to headquarters and work on the track.

A southwestern road is making a test on one roadmaster's district of the employment of an assistant roadmaster to relieve section forces of patrolling. If this works satisfactorily the practice will be used elsewhere.

A midwestern road has arranged for long patrols by patrolmen assigned Tuesdays through Saturdays. Patrolmen go one way one day and back the next day, except that they make a round trip on the third day. Section foremen will continue to patrol on Mondays. In some terminals on this road daily inspections are made on foot by track forces.

On another midwest road the section foremen no longer patrol track except in the case of one branch and a portion of main line. In lieu thereof, this road has assigned assistant track supervisors who are responsible for patrol, and who, in addition, have supervision over section gangs on their respective territories. In addition to saving man-hours, this practice has permitted the lengthening of sections and a reduction in the number of men.

A northwestern road has added 47 supervisors, under roadmasters, who will cover 60 to 80 miles of right-of-way each day, Tuesdays through Saturdays. The section forces will continue to inspect their territories on Mondays so there can be no excuse for their not being entirely familiar with conditions in their territories. This road has not changed the responsibilities of section foremen in regard to making an inspection at any time they feel it is required. On certain light traffic lines track inspections are not made on Saturdays or Sundays.

Another northwestern road proposes to use track inspectors covering approximately 90 miles of track daily, Wednesdays through Sundays. Track foremen will patrol track on Mondays and Tuesdays. A third northwestern road has set up relief for track inspectors in order to obtain a seven-day track patrol on lines having seven days' service. This road is working regular track inspectors four days one week and six days the next week, so that these men will have their relief one week on Saturday and Sunday and the next week on Sunday and Monday. It employs relief inspectors on relief days. Two other roads have put on patrolmen on certain districts to relieve section forces of patrolling.

college graduates are being employed as trainees and in some instances the men are taken from the ranks. Some roads work these trainees only under the better supervisors.

While all roads are trying to increase the daily production of their forces through better supervision, many are trying to impress upon their men that they are getting better wages and working less hours and, consequently, should do more in a day. Other roads are trying to capitalize on the statements made by the representatives of the organizations in negotiting the 40-hour week that the shorter work week should make the men fresher than under the 48-hour week, and, therefore, that they would produce more work per hour. This is being done in some cases by holding meetings of the supervisors, and sometimes of foremen, and asking them to impress this continually upon the men. Several roads report some results from this method, but many more are dubious of being able to do anything in this respect toward increasing daily production.

Patrolling Track

Seventy percent, or 44 roads, have not changed other than in a minor way their method of patrolling track. A number of these roads are now having track patrolled by assistants to roadmasters or to track supervisors. One of the roads which is so patrolling will continue to do so on Saturday, providing an adjustment in rate of pay for men so employed, and another is reducing the patrolling from six to five days. Four other roads have reduced patrolling to five days per week. One road is having its track patrol foreman work Tuesdays through Saturdays, and another Wednesdays through Sundays, with section forces patrolling on Mondays in the first case and on Mondays and Tuesdays in the other. Still another road has its track supervisors, under roadmasters, patrol six days per week, accumulating rest days for Saturday work until they have accumulated five days, and then laying off an entire week, being replaced by an extra supervisor.

Seven other roads are having roadmasters and/or supervisors patrol track on Saturdays. Three of them are studying the subject, one of which is considering small track patrol gangs to relieve section forces of patrol work. One road is trying to work out a joint arrangement with the signal department forces so that track defects or matters needing attention can be promptly reported on the rest days of the track force. Another states that a larger share of the track patrol will fall on supervisors. Five other roads use regular patrolmen Tuesdays through Saturdays, on the ground, or provide relief for patrolling.

Two roads advise they have no daily patrol, one that the heavier tracks makes it unnecessary; the other depends upon observations of supervisors, signal and telegraph maintainers and others who practically cover all of the main line daily in the performance of their regular duties.

About 30 percent, or 19 other roads, have made changes in methods of track patrol, six of these with little or no additional force. Three of these roads are doing patrolling with their present roadmasters, supervisors and/or assistants, and two of them state they are able to do this by shortening roadmasters' territories.

One road has discontinued daily patrol. In this case a track foreman is required to make a regular weekly inspection of main track turnouts and to note conditions on a prescribed form. Another employs trackwalkers where roadbed conditions, such as soft spots, bad cuts or bad fills make this imperative. Prior to the 40-hour week this was accomplished by regular section forces on an overtime basis. A third road has drastically reduced patrolling. Section forces are, as far as possible, located in the center of sections and are arranging to work their sections in opposite directions on alternate days, wherever possible, with a view of permitting the foreman to see his track in going to and from his work, at least once every three days.

One northwestern system, just prior to September 1, 1949, eliminated 211 sections and adjusted the remaining sections accordingly. This will be explained in more detail later.

Approximately 35 percent of all roads reporting state they plan to have more work done by extra or other special gangs and less by section forces. One road is putting an extra gang on each roadmaster's district so that heavy seasonal work can be performed by that force, and several other roads are now doing the same thing. Another road has intensified the development of small, permanently assigned district gangs, with the thought of attempting to do all work with these gangs on an out-of-face basis. A third hopes that the work of section gangs will be confined to that which can be done efficiently by small units taking care of day-to-day requirements. One road, however, stated that it expects to do more work with section forces.

Better Method of Doing Work

On most roads, according to several chief engineers, engineering officers and supervisors have been alert in developing and trying easier, better and quicker methods of doing work than had been used in previous years. One states that improvements come about gradually. Many report they are using every type of labor saving device available; others believe that the shorter work week will necessitate more extensive use of mechanical equipment. Two roads are studying the subject, and one of them states plans are being developed but that they are not yet ready for discussion.

A number of railroads are trying or considering different methods to increase efficiency; many of these methods are not new to a great number of roads but reference to a few of them may be of some benefit to others.

One road, by employing time studies in connection with its use of men and machines has improved the efficiency of doing work, and is sure that further improvement is possible. Another road is keeping cost data on rail laying and track surfacing operations and is studying them carefully to learn the cheapest way, and to see if further economies can be made. A third is endeavoring to analyze every operation to a much greater extent than heretofore to find a better way.

Several roads mention the use of ballasting and tamping machines as affording opportunity for economy, compared with older methods. One states that it has reduced the cost of raising track with these machines by approximately 35 percent over the use of other power tamping tools, and another that these machines and other labor saving devices have enabled it to keep up with the ever increasing labor rates and that it expects to obtain additional machines.

One road is trying to accomplish more maintenance per man-hour through more out-of-face work and another expects to do work more efficiently by using larger gangs well equipped with power tools.

Several mention the substitution of spray painting for brush methods as a source of greater economy.

Two roads are studying opportunities for greater economy in removing snow in yards; one of them is working on a proposal to handle snow with equipment, such as mechanical loaders and plows or ledgerwood unloaders, and the other is furnishing weed burners for cleaning snow from switches.

One road is now working with a local manufacturer to develop a machine for cleaning yard tracks. This machine is to remove all of the accumulated materials down to the tops of ties from between rails and between tracks. It will be able to load the materials directly into cars behind the machine, or on adjacent tracks. This will result in greatly improved conditions in heavy traffic yards and in a great saving in man-hours.

All roads, practically without exception, whether they have eliminated track patrol, reduced it, or have otherwise changed the method, are still continuing in effect their rules or instructions that section foremen, during abnormal conditions, such as storms, floods or other emergencies, making it unsafe for traffic, shall patrol their sections.

Lengthening of Track Sections

The lengthening of track sections has not been considered by 47 percent of the roads reporting. Several roads state that sections had already been lengthened, some during the depression and others more recently. Four roads feel the limit of length of sections has been about reached; one of them expresses the view that the 40-hour week has had the effect of reducing the size of section gangs 20 percent; another reports that some sections are now 20 miles long and branches 35 miles; while a third states that long sections increase the cost of travel time at the higher rates.

However, 53 percent of the roads reporting are considering the lengthening of sections. One states its sections have previously been lengthened and that further study is being made along these lines; also that its old policy of substantially uniform forces throughout the year will be dropped and that its extra and section gangs will be increased for seasonal work.

Another road advises that it is considering the lengthening of main line sections from 12 miles to from 14 to 18 miles, and the organization of a "bucket" gang on each roadmaster's district with a truck to handle all out-of-face work. How far they will go will depend upon the success of a test it proposes to máke.

Of the roads that have considered the matter, 40 percent of them have actually lengthened their sections. A recital of what some of these roads have done may be of interest.

On lines of northern road provided with heavy rail, improved ballast and block signals, double-track sections have generally been increased to 6 road miles or 12 miles of track, and single-line sections have been lengthened from 9 to 16 miles, except where bad shimming conditions exist. Also, where there are two or more sections in a terminal, this road has consolidated the gangs into a single gang under the jurisdiction of a foreman and one or more assistant foremen, and has staggered the work week for this gang so as to give six days' service. The brotherhood objected to this plan, but it has been put into effect.

An eastern road lengthened sections by reducing the total number from 108 to 79. A midwest road has reduced the number of sections on one division twice—the last time on September 4, 1949. The first reduction was from 35 to 28 sections and the recent reduction to 22 sections. This was brought about by improvement in track. Another midwest road has lengthened sections to 18 miles. A third midwest road, in many instances, has doubled up two section gangs, and has placed a foreman and assistant foreman in charge instead of two foremen. In other cases it has lengthened sections. This arrangement is to eliminate the general practice of supervisors bunching gangs.

A southern road is experimenting on one supervisor's territory on a fairly heavy traffic line of 90 miles, with a reduction in the number of sections from 8 to 3. A southwestern road is also experimenting on a roadmaster's district of 170 miles of secondary line and a 7 mile branch, with an arrangement which reduced 15 sections to 8. Another southwestern road has definitely lengthened sections. A description of what these three roads have done will be given later in more detail under the heading Changes in Organization.

A western road reports that the first rearrangement of sections was placed in effect on September 12, 1949, eliminating 20 of 141 sections, thereby lengthening the remaining sections. After this plan has been perfected, a second rearrangement is anticipated.

6 electric chain saws, 3 portable paint spraying outfits, and 12 miscellaneous electric tools for the bridge and building department.

During the summer of 1949 a northwestern road, in order partially to offset the increased costs of the shorter work week, purchased the following equipment:

> Fifty-nine 1½-ton trucks with dump body, five 1-ton panel trucks, 1 station wagon, 47 track inspection motor cars, forty 4-tool tamping outfits complete, 13 power rail drills, 7 power rail saws, 30 generator sets (complete with saws, drills, wrenches and pumps), one 16-in. power dirt drill, 1 power concrete buggy, two 75-ton air jacks, 1 concrete vibrator, 23 gas driven power chain saws, 14 floodlights for emergency use, and 10 hand-operated derricks for bridge, building and section gangs.

Types of equipment to be purchased by other roads (number was not given), include the following:

Adzers, tie
Ballast dressers and shapers
Bulldozers
Compressors, air
Cranes, small on-track
Cribbers (to be used ahead of adzers)
Draglines
Drills, track
Generators, electric
Jacks, power
Mowers, tractor
Pullers, spike
Scarifiers
Tampers, air and electric
Weed burners
Ballast cleaners
Ballasting and tamping machines
Complement of tools for B & B gangs
Cranes, diesel electric, locomotive-type
Cribbing machines
Discers
Drills, air and electric
Drivers, spike
Grinders, rail
Mower, on-track
Off-track equipment replacing on-track
Saws, rail
Shovels, crawler
Tampers, spot
Wrenches, power

Of the above equipment, ballasting and tamping machines were mentioned more times than any other three pieces of equipment combined. Next in order were the cribbing machines, tie tampers, ballast cleaners and various power tools for bridge and building gangs.

A number of roads are studying means of extending the use of their present equipment but their plans have not been fully worked out. Several methods have been suggested to accomplish this, such as better planning and allocation of its use, programming of transfers from one territory to another, closer and more effective preventive maintenance, by supervision to insure that machines are kept busy, by additional tricks per day, relief crews, new uses of machines, and putting track maintenance on a program basis, scheduling the work to be done by power equipment so that lost time will be reduced and greater use obtained.

Some machines lend themselves to more than one use. For example, a tractor mower can be used not only as a mower; it is also being used by some roads as a ditcher, and as a plow or broom in removing snow from platforms and driveways. One road states that it originally purchased trucks for handling materials but that their use has been expanded to include the transporting of men and to the removal of snow from yards and platforms. Some roads are endeavoring to find machines that can be used more universally so that, if possible, year round services can be obtained.

Two roads mention the need for a machine for tie renewals. One states this is a most accute problem and that little progress has been made in its solution to date. This road is endeavoring to develop something that will speed up the work of tie renewals. Another road is developing machines for sloping and finishing ballast shoulders.

Mechanical equipment and tools are saving the railroads many hours of labor and are probably helping the railroads meet the present situation and past wage increases, more than any other factor. A number of roads advise that they have sufficient equipment at the present time, since they have been purchasing all types of labor saving equipment for some years in the past, with extensive purchases during the past five to ten years. These roads plan to continue purchasing machines for replacements and are on the alert for any new machines that may be introduced.

However, more than 70 percent of the roads reporting are considering the expansion of their complements of equipments by the purchase of more of the same types of machines and machines of other types. Some roads still have the matter under study, but a majority of them have decided what they require and some of them have already placed orders for additional machines. Some roads state that the increased cost of labor has made many machines more attractive and more economical than before.

The following equipment is being considered by a western system:

Track department.—Mechanical tampers, adzers, rail laying cranes, bonding drills, rail drills, rail saws, spike drivers, spike pullers, tie pullers, weed mowers, weed burners, weed spraying equipment, crawler tractors with bulldozers and cranes, end loading tractors, snow brooms, tractors with plows for plowing fire guards, tractor scrapers and welding equipment.

Bridge and building department.—Air compressors and pneumatic tools such as drills, wrenches, saws, hammers, paving breakers, sheet piling hammers, hydraulic jacks, electromagnets, concrete mixers, sump pumps, floor sanders, paint sprayers, concrete vibrators, etc.

Signal department.—Same tools listed above where they can be used, and in addition power trenching machines, portable or crawler mounted cranes and post hole diggers.

A midwest road is equipping more of its bridge and building crews with a set of electric power tools. About two-thirds of its crews are now so equipped, and to equip the remaining crews will require: Five portable electric generators, five chain saws, five circular saws, five drills, five nut runners. For track maintenance, this road will require two ballasting and tamping machines, four power jacks, four 4-unit tamping machines, three rail drills, and one off-track mower.

The chief engineer of a southwestern road is asking for authority to purchase the following labor saving tools and equipment: 12 electric generators, 12 timber saws and conductors, 12 electric drills, 12 electric impact wrenches, 12 electric hand saws, fifteen 4-tool electric tie tampers, fifty 30-cu. ft. compressors for tie tampers, 200 tie tamper tools, 50 impact wrenches, 7 power rail saws, 10 rail drills, 2 spike driving machines, 2 cribbers, 1 road roller and 2 crawler tractors.

An eastern road is planning to purchase the following additional equipment for use in 1950 to offset the increased costs of the shorter work week and to increase maintenance efficiency: 2 ballasting and tamping machines, 2 crib cleaning machines, 4 stock rail grinders, 4 pneumatic spot tampers, 4 bulldozers with angle dozers, 3 diesel locomotive cranes, 3 off-track mowing machines, 1 pressure grouting machine, 1000 gas switch heaters, 15 sets of automatic crossing gates, 6 power track wrenches, 2 power jacks, 1 power road scraper, 2 crawler crane and shovel combinations, 6 auto trucks for roadway mechanics, 3 portable welding machines, 6 trailer mounted air compressors,

motor cars. A few roads report that while they are using trucks they have permitted their forces to retain their motor cars for use at points where motor cars can be used more economically.

The chief engineer of one company is of the opinion that he gets greater return on the investment in trucks than from any other labor or time saving equipment, and another states that trucks, for transporting both section and extra gangs are one of his greatest labor saving devices.

One road reports that track cars are now used regularly only by track patrols, inspection parties, section gangs and signal maintainers.

A southern road is giving serious consideration to a reduction in the use of track motor cars and hopes to supply all its line forces with trucks within two years and thus eliminate entirely the use of motor cars by the track forces. Motor cars will be used only by signal maintainers, and then only at points that cannot be reached readily with a small automobile truck.

Most of the roads supplied complete details regarding the use of highway transportation by their forces. Among those mentioned most were the section forces, almost half of them being confined to terminal and yard sections. These were followed closely by bridge and building forces; then in order by extra gangs, signal gangs, water service men, work equipment mechanics, district maintenance gangs, signal maintainers welding gangs, and miscellaneous forces.

A midwest road has decreased the use of motor cars materially. At the present time all of the main line signal maintainers and section gangs are transported from headquarters to points of work in trucks, which are also used by about 50 percent of its extra gangs, and this program will continue.

A southern road now has about 200 trucks assigned to its maintenance of way department and expects to purchase more. Trucks are assigned to practically all extra gangs, bridge and building forces, and the men who maintain work equipment. A number of trucks also have been assigned to yard sections, but only a very few to section gangs, and they are on an experimental basis.

Another southern road is combining sections, making resident gangs, and is using trucks for transportation.

A third southern road has at present 186 trucks of various sizes and descriptions, in use by the maintenance of way department, It also has in this department 21 automotive units, 4 house trailers, one tractor trailer and one semi-trailer—total of 213 units. Additional units are being acquired for section, extra gang, bridge and building, welding supervisory and other forces for all heavy traffic lines. Experience demonstrates that, when properly assigned, the investment in the truck unit can easily be returned in the first year's operation, allowing for a more intensive use of available man power and increased efficiency of supervision. While the use of motor cars is curtailed under the highway vehicle program, this road has made no great reduction in the number of motor cars, because all forces equipped for highway transportation also have motor car transportation available for use in emergency and for inspection and, in the case of floating forces, for use where highways are not accessible for truck transportation.

A northwestern road, in the summer of 1949, purchased 65 additional trucks for highway use, principally by maintenance gangs and bridge and building gangs. All of these gangs will still have motor cars available for their use when they can be operated economically. Regular section gangs will still use track motor cars except, in cases of emergency and special work.

Many roads are not planning any further extension of the use of present equipment because they have been endeavoring to keep all equipment working to the utmost. One has done so by keeping an accurate record of the availability and uses of machines in order that they would not be standing idle. Some roads advise that the five day week will prevent them from getting as much work done as they were getting done in the six day week.

The proper maintenance of power tools and machines is of paramount importance in order to keep such equipment in continuous service, and the roads seem to be alert to this situation. A number of roads are expanding their repair facilities or equipment maintenance forces or both, or are making other changes to this end.

One road, not satisfied with its present methods of maintaining its work equipment, has started on a program of building new division shops for maintaining equipment. This road has already built one such shop and has authority for another. It believes it can maintain some classes of equipment to better advantage on the divisions than in a central shop. Another road is giving consideration to the construction of a new maintenance of way repair shop, while two others are contemplating an expansion of their equipment repair shop facilities.

The expansion of repair force is reported as necessary on two roads to handle properly the ever increasing number of machines used, and another road reports that in the past two years it has completely reorganized its maintenance of work equipment forces. Two other roads have added traveling roadway machine mechanics, or maintainers, to keep machines repaired and in working order, thereby avoiding time in the shop and the delaying of work in field. These men will also make up shop programs, when necessary, to keep the machines in the best possible condition. Another road is considering the assignment of a special equipment supervisor.

A plan of intensifying the method of taking care of small parts requirements and minor repairs in the field is under consideration by one road, while another advises that the maintenance of equipment has been taken over by the maintenance of way department.

Many of the roads are not contemplating any changes in the maintenance of their equipment, since they already have efficient organizations and shops for doing this work.

The methods adopted by one road for maintaining its power equipment are of interest. It is operating a central maintenance of equipment repair shop and, in addition, has traveling roadway mechanics, each supplied with a van body truck which is equipped to make line-of-road repairs on all units of equipment. These trucks are adequately equipped with a select complement of machine parts, small lathes, drills, grinders, welding equipment and other necessary machine tools, built into the body to carry out as much field maintenance as practicable. The mechanics are assigned to specific territories, usually an operating division, and are responsible for the maintenance of all roadway equipment on their respective territories. They are under a supervisor of roadway equipment and they determine whether repairs are to be made in the field or in the shop. They keep the maintenance officers currently informed as to the condition of all equipment so that proper shopping sequences can be arranged. Present items of mechanization on this road number more than 700 gasoline or diesel operated units, exclusive of motor cars and automotive equipment.

Highway Transportation

The use of trucks and other highway vehicles has increased since your committee reported on this subject in 1946. More than 75 percent of the roads reporting are making use of them and the majority of these roads have thus been able to reduce the use of

The answer of one road to the problem of reducing work-train service is grading the right-of-way for the use and movement of off-track equipment. Some of the other methods suggested for reducing work trains are: Better and more careful planning and programming of work in advance; constantly keeping before all concerned that the maximum possible work must be attained; accumulating work train duties to reduce the cost of deadheading and arbitrary payments; larger power; and closer cooperation with the transportation department as well as with the mechanical department. Some roads advise that they have obtained excellent results from the use of these methods.

The reduction of work trains is well covered in the statement of a chief engineer of an eastern road who says that the most important step to be taken to reduce the number of work trains is to sell the transportation department the importance of a work train and impress upon it the costs involved in any delays to this train. Work trains can be reduced 50 percent with the cooperation of the transportation department by clearing only first class and important symbol trains, and by detouring extra freight and local trains with only slight delays to such trains. Careful planning and proper supervision are necessary to obtain maximum service of work trains, and where crane work is required, sufficient cranes should be included in the work train to perform such work in the minimum time. Where trains are being detoured for track raising or other reasons, work trains should be utilized at the same time to perform any operation requiring work train service.

Improvement in Track

Most of the roads report they are making no change in the track structure because of the shorter week, stating that for some years past they have been using larger treated ties, improved and better ballast, and heavier rail, and expect to continue such a program. Many have been, and continue the stabilizing of roadbed by grouting and driving poles, and some are planning to augment their programs for such corrective work.

Several roads are increasing the number of ties to the panel. One is now using nine-foot ties, two others are considering the use of nine-foot ties, while a third road states it has arranged for larger and longer ties. Among the improvements now being made in ballast is the use of heavier ballast sections, the use of crushed stone instead of gravel, and an extension of the use of trap rock.

A few roads advise they have recommended the use of heavier rail. One road thinks it would be advisable to increase the length of rail to 117 ft. A number of roads are using, or are considering the use of continuous welded rail—a majority of them in special locations, such as through station grounds, road and street crossings, and in tunnels and on bridges.

Also mentioned as having been instituted to improve track and reduce maintenance were the cleaning of ballast, widening of cuts and fills, and improving drainage.

One road considers that under present high speed operation it is necessary to build track to a higher standard than fomerly. Another states it has done a great deal to increase the permanency of construction to obtain benefits in reduced maintenance expense. A third road is of the opinion that, with the ever increasing use of diesel power, the present standard of material in main line track will give a greater life than formerly under steam operation.

Improvement in Structures

In general, it has been the practice for years to study and look for new, improved materials and methods in the construction and maintenance of structures and, when found, to apply them in the interest of reduced cost of maintaining such structures. It is

A number of other roads are using highway vehicles at special locations or on certain parts of line. One midwest road, however, states that it has attempted to use highway trucks but has found them unsatisfactory.

Portable Houses

There is substantial unaminity that the shorter work week will have no effect on the greater use of portable houses in lieu of camp cars. Many roads have never used portable houses, some saying that camp cars are more flexible and of advantage in moving a gang from place to place, particularly in emergency. Two roads, while not using portable houses, do not intend to make more extensive use of camp car equipment. One of these roads states that it is only using camp cars for the few extra gangs it may have, such as system rail gangs, and bridge and building gangs, and for special equipment operators.

One road has one portable off-track camp outfit on each main line division, but does not feel that additional housing of this type is needed and in many cases these portable outfits will be used in conjunction with camp car equipment, when necessary to enlarge normal extra gangs to take care of larger program work. Another road has used a few portable houses for housing section laborers, and a third uses them only for jobs of extended duration for bridge and building gangs. A fourth road has made use of portable houses but states that it cannot see where there is any economy in so doing.

Work Trains

Reduction in the number of work trains and a decrease in their costs is not a new problem to the railroads but it is one in which many roads are still vitally concerned in making further reductions. Some roads are now using work trains only on major projects such as loading and unloading rails, distributing ballast, and on certain bridge jobs. A number of roads have helped to solve the problem by using local freight trains instead of work trains, but on one road the use of the locals for that purpose is limited to two hours per day. Another road is using extra freight trains for unloading ballast and to deliver carload material and uses cranes and motor cars to distribute the material Emergency deliveries are made by trucks.

One road expects to hold work trains to a minimum by its increased supervision Another road is keeping a closer check on supervisory forces, which normally arrange for work trains, to see that the work is coordinated so that the minimum number of work trains will be required. A third road advises that, since September 1, by a more coordinated delivery of materials and the use of work trains, it has greatly reduced its work train mileage.

A majority of the roads reporting have effected a reduction in the number of work trains by the use of off-track equipment, such as bulldozers, carryalls, front end loaders, crawler cranes, draglines and shovels, spreaders, trucks and other types of equipment, and the use of such equipment will be expanded by the purchase of additional units. One road, by the use of tractors with special track dressing equipment, is eliminating work formerly handled by work trains. Some roads have eliminated work trains for ditching and bank restoration by using some of the above equipment, except in heavy rock cuts where there is insufficient room for the efficient use of off-track equipment. Auto trucks, dump trucks, highway truck tractors with low bed, heavy duty trailers and other types of equipment are being used in connection with grading work and for the distribution of equipment, materials and supplies, eliminating work trains for such purpose. One road that is using off-track equipment states that it has not found any such equipment that will perform certain jobs as economically as some particular piece of on-track equipment.

With the elimination of regular patrol work, a southwestern road has assigned to section gangs programs of out-of-face normal tie renewals, adjusting rail anchors, tightening bolts, spotting and lining track, and dressing ballast shoulder—in other words, doing a complete job of track maintenance work. The sections are required to continue this program of out-of-face work each day, except as may be otherwise directed by the roadmaster. A record is kept of the progress of the program work which has been termed "flat work," and at the end of each month the roadmaster reports the distance each section has covered. These reports are tabulated by the division engineer to show the amount of flat work completed on the division each month.

Slightly over two years ago, another southwestern road started the experimental use of permanently assigned "bucket" gangs on various territories, which were referred to as "district" gangs. These gangs were given territories of 50 to 80 miles and were outfitted with highway trucks and suitable labor saving equipment, such as tie tampers, etc. Since that time the number of these gangs has been gradually increased and an effort has been made to do all maintenance work possible on an out-of-face basis with these gangs. Section gangs, with very substantially increased mileage, are used primarily for spot maintenance, care of switches, patrolling, etc. This road has found that this plan gives much better results for the maintenance dollar and, effective September 1, 1949, this system of organization was drastically increased. Now, more than 80 percent of the trackage of this road is on this basis of maintenance, and it is expected that in a few months the entire system will be so organized.

The elimination of 211 sections was made by a northwestern road, and, at the same time, 37 permanent maintenance or floating gangs were added, bringing the total of such gangs to 42. The size of these gangs will be increased during the working season to do more out-of-face work, which was formerly performed by section forces.

Several years ago, a southern road began a program of assigning permanent maintenance extra gangs on the basis of one to a roadmaster's district to perform out-of-face surfacing operations. When this was done sections were lengthened. As a result of this experience, it is said that this road will make further changes in its organization in which the trend will be toward larger forces and to relegate section forces to a function of inspection and the correction of small items.

Another southern road is conducting an experiment on a 90-mile supervisor's territory of fairly heavy traffic, by reducing the number of sections from 8 to 3, adding an extra gang and providing a truck for each section force and for the extra gang. It has added an assistant supervisor, who will spend practically all of his time on a motor car inspecting the track and arranging for the performance of work which he finds necessary. This organization was put into effect on June 15, 1949, and it is too early to determine how it will work out.

On one roadmaster's district, a southwestern road is changing the system of maintenance, and if it works satisfactorily this road expects to use it elsewhere. The district has 170 miles of secondary main line and a 7-mile branch. On most of the district traffic consists of one passenger train each way daily and a tri-weekly local. On about 23 miles there are, in addition, 2 manifest freights each way, and on the 7-mile branch there are the manifest freights only. Track is laid with 85, 90 and 110-lb. rail, and is all ballasted with gravel or crushed stone. At present there are 15 sections on the district and extra gangs are used for rail laying, etc. It is proposed to reduce the organization to eight sections and one fully mechanized extra gang, doing only light maintenance with the section forces and all heavy maintenance with the extra gang. An assistant roadmaster will be added to relieve the section forces of all patrolling and inspection, except during

thought that the shorter work week may increase efforts in this direction. One road now has no wood bridges, advising that all are steel or concrete, or a combination of both. Several others agree that the trend will be toward more permanent structures.

Following are some of the things a number of roads have done, have in progress, or are considering to reduce the cost of maintaining bridges: Replacing timber bridges with steel or concrete, or both; replacing timber trestles with concrete trestles; filling trestles and replacing them with pipe culverts; replacing open deck trestles with permanent structures or ballast deck trestles; using concrete slabs to replace short spans; increased use of treated timber; pressure grouting of tunnels and stone masonry; the use of tie pads on bridge ties; the use of a better quality of paint; extended use of paint sprayers; and increased mechanization of gangs.

To reduce the cost of maintaining buildings and other structures the following items are mentioned: More careful design; simplifying buildings; wherever feasible, retiring buildings or reducing their size; substituting concrete, steel, brick, tile and concrete blocks for timber; the use of steel buildings for the portable type; the use of long life, fireproof or fire retardant materials; asbestos shingles or siding material for walls of buildings; the use of copper or other nonrusting material for leaders, gutters, etc.; the use of glass blocks in place of windows and frames; the installation of automatic electric power operation instead of manual in water stations; substitution of remote control switches and centralized traffic control for interlocking plants and towers; elimination of primary battery actuation of signals by the use of central station electric power, where available; and the substitution of flashers and/or automatic gates for gate houses and gatemen.

Changes in Organization

Practically 80 percent of the roads have made no change in their maintenance organizations, but a number of them have considered changes without reaching any decisions. Some think it is too early, and prefer to wait and check from experience with the shorter week. One road cautions that it is better to adjust organizations slowly to new conditions, thus avoiding the shock and confusion of sudden changes. One road is counting on increased supervision to offset increased costs. Another is planning closer cooperation between men and supervisory officers, stating that its experience is that a laborer or semi-skilled workman, by working very little harder, but with greater interest in his job, can more than overcome the reduction in man-hours.

A number of roads have made changes in their organizations or have definite plans that are being considered. With the thought that these changes may be of benefit to others they are outlined in the following:

A northwestern road is giving consideration to the organization of one large crew at its larger terminals, with buses or trucks for transportation around the terminals. This plan is favored on the western district of the railroad but is not considered practical on the eastern district. The eastern part of the railroad is faced with heavy snows and extremely cold weather, where it has been considered better to have two and three small gangs scattered than to have one large crew. In case of snow trouble with several sections, the crews are already spread out. With one crew there would be times when it would be quite a problem to get men to outlying points on the terminal.

The bunching of gangs into larger units to perform the work more efficiently is the principal change made by an eastern road. Another eastern road advises that the use of ballasting and tamping machines will enable it to reorganize its track raising gangs, and in 1950 will reduce labor for track raising by 200 men. This road is also planning to reduce the number of section, bridge, building and telegraph construction gangs and use larger gangs to expedite work and reduce costs.

(f) Reduction of overtime by a careful study to keep it to the minimum.

(g) The closest possible cooperation with the transportation department so that maximum production can be obtained with minimum interruption or delay to traffic. For such work as rail laying, applying ballast and renewing bridge decks, it may be possible to divert traffic, or trains may be grouped together to provide longer working periods.

(h) Reducing or eliminating as much as possible the physical property which requires maintenance.

(i) Continue to educate men in safe practices.

(j) Decrease number of reports that are required from maintenance forces.

(k) A statement was also made that supply associations are doing a good job in the constant development and improvement of machines and appliances to reduce maintenance costs, and it was suggested that there should be closer cooperation with supply associations, and that the AREA might take the lead in this matter.

Conclusions

1. All roads reporting are working their forces Mondays through Fridays, except relief men. About 40 percent of the roads are staggering some forces, mostly in yards and terminals; some are limited in staggering forces to the winter months, while a few are accumulating rest days for certain forces. Some floating gangs on some roads are being allowed to make up time lost in going home over week ends. The matter of staggering forces has been submitted to a 40-Hour Week Committee by a numbeı of roads.

2. It is the opinion of most roads that more alert, intensive and closer supervision is necessary to offset the increased costs of the shorter work week. However, 75 percent of them do not propose to increase supervisory force to obtain this end. Seventeen percent are definitely increasing such force, and the balance are considering additional forces or realinement or reassignment of existing forces. While a majority feels that training of supervisors is desirable, only a small percentage have training courses, and more roads are giving supervisors training on the job, mostly by appointing assistants for that purpose. Some are employing young college graduates as trainees.

3. There is an increasing movement to relieve section forces of the duty of patrolling track as much as possible, except in cases of emergency.

4. A majority of roads are considering the further lengthening of track sections, and 40 percent of those considering it have actually lengthened sections. More than one-third of all roads reporting on the matter are having more work done by extra or other gangs, or planning to increase the work done by such gangs.

5. The railroads for many years have been on the lookout for quicker and better methods of performing work, largely by mechanization, and this effort is being intensified.

6. The shorter work week has accentuated the purchase of power tools and machines. The importance of the proper maintenance of such equipment to keep it in as continuous service as possible is readily recognized by the roads and a number of them are now engaged in the expansion of their equipment maintenance forces and facilities.

7. The purchase of trucks and other highway vehicles for the transportation of maintenance forces, material and equipment has been extensive and is continuing to increase. The use of these vehicles varies on different roads in accordance with local conditions, but on some roads practically all classes of maintenance forces have highway vehicles assigned to them—principally trucks. This has materially reduced the use of track motor cars.

storms, etc. The extra gang will be furnished such equipment as ballasting and tamping machine, a power jack, power wrench, truck, outfit cars, etc., and it will be expected to put in all ties, do out-of-face surfacing, etc. At present the section forces put in all ties, etc., and are equipped with motor cars and four-tool tampers.

Better Grade of Men

There is a wide divergence of opinion as to whether the increased rates of pay and the shorter work week will enable the railroads to obtain a better grade of men. About half of the roads believe that they will be able to obtain better men, but with some reservations, about one-third of the roads definitely think they will not; others are doubtful, and a few are hopeful.

Most roads feel the need for a better class of men, and many think they will be able to obtain them by a closer and more careful selection and screening of new men before accepting them for service. Some are impressing the necessity of this upon supervisors and foremen. A number advise that if a man does not produce he will be dismissed. Others state that for years the primary obstacle to securing desirable workmen has been the lower rates of pay. Now rates compare rather favorably with those in other industries, and together with the shorter work week puts railroads on a level with other principal industries. One eastern road states that it expects to get a better grade of men in highly industrial areas, such as New York and Buffalo.

Some feel that better men will desire to remain on seniority lists which will result in less changes in personnel. A few think that to obtain a better grade of men it will be necessary to advertise more effectively the improved quality of the jobs in railroad maintenance. Several are of the opinion that the ability to get better men will depend not only on rates of pay, but also on accommodations and working conditions, which at present are lacking compared with outside industries. With this in mind one road is furnishing suitable camp cars for floating gangs and is making things more pleasant for section forces by permitting them to live in towns of suitable size instead of holding them at outlying points where schools and living conditions are not satisfactory.

It is the thought of a few that obtaining better men will be limited to certain locations, such as rural areas. A number who consider the present situation as temporary feel that the ability to obtain better men will depend upon the general labor market and that in period of extreme labor shortage it is likely that contractors and other employers will raise labor rates.

Those who think they will not be able to obtain a better grade of men base their thinking on the problem presented by seniority; that the source of labor supply has not changed and the increased rates of pay are still somewhat lower than in other industries.

Other Means and Methods

Other means and methods suggested to help offset the increased costs of the shorter work week include the following:

(a) Better planning and programming of maintenance work.

(b) More stabilized programs from year to year.

(c) Campaign governing use of material to avoid waste, keeping all materials picked up and carefully sorted before being disposed of as scrap.

(d) Educate supervisory forces, including foremen, in the present cost of labor and materials.

(e) A program of publicizing the amount of work certain gangs are doing, with the idea of stirring slower foremen to greater production.

Report of Committee 28—Clearances

A. R. Harris, *Chairman,*
J. E. Armstrong
C. O. Bird
E. S. Birkenwald
A. B. Chapman
S. M. Dahl
W. T. Davis
F. S. Drouet
J. E. Fanning
N. O. Geuder
C. D. Horton
E. R. Logie
R. R. Manion
R. C. Nissen
C. E. Peterson
W. F. Pohl
A. M. Weston, *Vice-Chairman,*
W. E. Quinn
J. H. Shieber
J. E. South
J. W. Wallenius
J. G. Wishart
E. R. Word

Committe

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, comprising recommended revision, on the following page.

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, Engineering Division, and with Mechanical and Operating—Transportation Divisions, AAR.

   No report.

3. Clearance diagrams for recommended practice, collaborating with committees concerned.

   No report.

4. Compilation of the railroad clearance requirements of the various states.

   Progress report, revised, presented as information on the following page.

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating with the Mechanical Division, AAR.

   No report.

The Committee on Clearances,
A. R. Harris, *Chairman.*

Bulletin 484, December 1949.

8. The shorter week has had no effect on the use of portable houses in lieu of camp cars. Even those roads using portable houses are expanding their use very little, if at all.

9. The use of work trains has been reduced over the years and is continuing to be reduced considerably by the use of off-track equipment. A reduction in the costs of work trains may be obtanied by careful planning and supervision, and by cooperation with the transportation department.

10. Improvements in the track structure to reduce maintenance requirements have been in progress on most roads over a period of many years, and are being continued These improvements consist of the use of larger and longer treated ties, improved and better ballast, heavier rail, stabilization of roadbed, the use of continuous welded rail, cleaning of ballast, widening of cuts and fills, and improved drainage.

11. A reduction in the maintenance costs of structures has been and is being accomplished by more careful design; continual study and search for more permanent and longer life materials; reduction in the size of structures or their elimination, where feasible; and by the mechanization of forces.

12. Most of the roads are making no changes in track maintenance organization but a number are considering and some have already made changes. The principal changes being made involve assigning more work to district or floating gangs, and less work to section forces.

13. The increased rate of pay and the shorter work week place the railroads on a more comparable basis with other industries. This may make it possible to obtain a better grade of men by careful selection and screening of new men, and their desire to remain on the seniority list. But this may be limited to rural areas. Whether the railroads will be able to attract a better class of men will depend to some extent upon the general labor market and the fact that elimination of unproductive employees may be slow because of seniority. In a number of cases railroad wages are still somewhat lower than in industry, and in certain localities the source of labor supply remains unchanged, both of which factors makes the task of obtaining a better grade of men more difficult.

14. Better planning and programming of work, reduction of overtime, closest cooperation with the transportation department to minimize loss of time by maintenance forces due to train interruptions, and continued education in safe practices, are other means suggested to offset increased costs.

Report on Assignment 1

Revision of Manual

J. E. Fanning (chairman, subcommittee), J. E. Armstrong, W. F. Pohl, W. E. Quinn, A. M. Weston, E. R. Word.

Your committee recommends the following revision:

Pages 28–1, Special Notes, change sentence reading "The clearances on tangent track shall be not less than shown," to read, "The clearances shown are for tangent track."

Report on Assignment 4

Compilation of the Railroad Clearance Requirements of the Various States

C. D. Horton (chairman, subcommittee), A. B. Chapman, S. M. Dahl, W. T. Davis, F. S. Drouet, J. E. Fanning, N. O. Geuder, E. R. Logie, R. R. Manion, R. C. Nissen, C. E. Peterson, J. H. Shieber.

Your committee submits as information, a tabulation of the Clearance Requirements of the various States, brought up-to-date as of June 1949.

Report of Committee 17—Wood Preservation

G. B. Campbell, *Chairman,*
W. P. Arnold
W. W. Barger
J. A. Barnes
A. S. Barr
R. S. Belcher
P. D. Brentlinger
Walter Buehler
C. M. Burpee
C. S. Burt
G. L. Cain
H. B. Carpenter
W. F. Clapp
J. W. Diffenderfer
R. F. Dreitzler
H. R. Duncan
W. F. Dunn, Sr.
T. H. Friedlin
W. H. Fulweiler
H. F. Gilzow
W. R. Goodwin
F. W. Gottschalk
F. A. Hartman
B. D. Howe
M. S. Hudson
R. P. Hughes
M. F. Jaeger
A. L. Kammerer
N. E. Kittell
L. W. Kistler, *Vice-Chairman,*
A. J. Loom
G. L. P. Plow
R. R. Poux
J. W. Reed
W. C. Reichow
Henry Schmitz
F. S. Shinn
L. B. Shipley
J. E. Tiedt
H. C. Todd, Jr.
Hermann von Schrenk
C. H. Wakefield

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Service test records of treated wood.

   Progress report, presented as information .... page 344

3. Destruction by marine organisms; methods of prevention.

   Progress report, presented as information .... page 351

4. Creosote-petroleum solutions.

   Progress report, including recommendation for addition to Manual ...... page 355

5. Destruction by termites; methods of prevention.

   No report.

6. New impregnants and procedures for increasing the life and serviceability of forest products.

   Progress report, presented as information .... page 356

7. Incising forest products.

   Progress report, presented as information .... page 356

8. Use of straight coal tar for tie treatment and results obtained.

   No report.

9. Review the specifications for creosote, particularly with respect to limitation of residue above 355 deg. C., and other revisions resulting from changes in processes of manufacture.

   No report.

AREA Bulletin 484, December 1949.

GREAT NORTHERN RAILWAY

9337 Creosoted White Birch Test Ties Originally Placed 1908

Year	*Number Removed Each Year*	*Accumulative Total Removed*	*Percent Removed*	*Number of Years in Service*	*Tie Year Life*	*Accumulative Tie Year Life*	*Average Life of Ties Removed in Years*
1908	0	0	0	0	0	0	----------
09	0	0	0	1	0	0	----------
1910	0	0	0	2	0	0	----------
11	0	0	0	3	0	0	----------
12	10	10	0	4	40	40	4.0
13	90	100	1	5	450	490	4.9
14	115	215	2	6	690	1,180	5.5
1915	230	445	5	7	1,610	2,790	6.3
16	360	805	9	8	2,880	5,670	7.0
17	36	841	9	9	324	5,994	7.1
18	36	877	9	10	360	6,354	7.3
19	994	1,871	19	11	10,934	17,288	9.2
1920	79	1,950	21	12	948	18,236	9.4
21	39	1,989	21	13	507	18,743	9.5
22	240	2,229	24	14	3,360	22,103	9.9
23	402	2,631	28	15	6,030	28,133	10.7
24	136	2,767	28	16	2,176	30,309	10.9
1925	29	2,796	29	17	493	30,802	11.0
26	278	3,074	32	18	5,004	35,806	11.6
27	201	3,275	34	19	3,819	39,625	12.1
28	221	3,496	37	20	4,420	44,045	12.6
29	221	3,717	39	21	4,641	48,686	13.1
1930	359	4,076	43	22	7,898	56,584	13.9
31	96	4,172	44	23	2,208	58,792	14.1
32	86	4,258	45	24	2,064	60,856	14.3
33	48	4,306	45	25	1,200	62,056	14.4
34	52	4,358	46	26	1,352	63,408	14.5
1935	14	4,372	46	27	378	63,786	14.6
36	95	4,467	47	28	2,660	66,446	14.9
37	100	4,567	48	29	2,900	69,346	15.2
38	210	4,777	50	30	6,300	75,646	15.8
39	363	5,140	54	31	11,253	86,899	16.9
1940	374	5,514	59	32	11,968	98,867	17.9
41	430	5,944	64	33	14,190	113,057	19.0
42	186	6,130	66	34	6,324	119,381	19.5
43	164	6,294	67	35	5,740	125,121	20.0
44	220	6,514	70	36	7,920	133,041	20.4
1945	301	6,815	73	37	11,137	144,178	21.2
46	402	7,217	77	38	15,276	159,454	22.1
47	290	7,507	80	39	11,310	170,764	22.8
48	398	7,905	84	40	15,920	186,684	23.6

Straight Creosote Treatment 8.2 lb. per cu. ft.

10. Treatment of wood to make it fire resistant.

No report.

11. Artificial seasoning of forest products prior to treatment.

Progress report, presented as information .... page 359

THE COMMITTEE ON WOOD PRESERVATION,
G. B. CAMPBELL, *Chairman.*

Report on Assignment 2

Service Test Records of Treated Wood

A. J. Loom (chairman, subcommittee), T. H. Friedlin, W. R. Goodwin, R. P. Hughes, G. L. P. Plow, J. W. Reed, W. C. Reichow.

The following report of test records is submitted as information:

The U. S. Forest Products Laboratory reports on 1948 inspection of experimental ties in the University Avenue and Fair Grounds (Madison, Wis.) and Hartford, Wis. test tracks of the Chicago, Milwaukee, St. Paul & Pacific Railroad.

The Great Northern Railway reports on service records of white birch cross ties treated with straight creosote and with creosote-petroleum solution.

GREAT NORTHERN RAILWAY

2316—White Birch Test Ties—Stone Arch Bridge G. N. Ry. Minneapolis.
Creosote—Petroleum Treated—50-50 Mixture Originally Placed 1924.

Year	Number Removed Each Year	Accumulative Total Removed	Percent Removed	Number of Years in Service	Tie Year Life	Accumulative Tie Year Life	Average Life of Ties Removed in Years
1924	0	0	0	0	0	0	0
25	0	0	0	1	0	0	1
26	0	0	0	2	0	0	2
27	0	0	0	3	0	0	3
28	0	0	0	4	0	0	4
29	0	0	0	5	0	0	5
1930	0	0	0	6	0	0	6
31	0	0	0	7	0	0	7
32	0	0	0	8	0	0	8
33	0	0	0	9	0	0	9
34	0	0	0	10	0	0	10
1935	0	0	0	11	0	0	11
36	0	0	0	12	0	0	12
37	0	0	0	13	0	0	13
38	0	0	0	14	0	0	14
39	0	0	0	15	0	0	15
1940	29	29	1.2	16	464	464	16
41	38	67	2.9	17	646	1,110	16.6
42	5	72	3.1	18	90	1,200	16.7
43	8	80	3.4	19	152	1,352	17.0
44	10	90	3.9	20	200	1,552	17.2
1945	206	296	12.8	21	4,326	5,878	19.8
46	53	349	15.0	22	1,166	7,044	20.1
47	88	437	18.9	23	2,024	9,068	20.7
48	135	572	24.7	24	3,240	12,308	21.5

						Ties set 1927—21 years service								
Borax	F	Red oak	H-S	.59[i]	98	57	58.2	30	30.6	11	11.2			24[e]
Borax	F	Red oak	H-S	.24[i]	100	38	38.0	42	42.0	20	20.0			21[e]
Zinc chloride	F	E. hemlock	S	.62[c]	112	51	45.5	27	24.1	34	30.4			22[e]
Zinc chloride	F	Yel. birch	S	.67[c]	129	33	25.6	55	42.6	41	31.8			19[e]
Zinc chloride	F	Corkbark fir	H-S	.45[c]	78	21	26.9	11	14.1	45	57.7	1	1.3	19[e]
C. t. creosote, grade 1[g]	F, E	Corkbark fir	H-S	10.11	40	23	57.5	3	7.5	14	35.0			23[e]
						Ties set 1925 to 1927—21 to 23 years service								
C. t. creosote, grade 1[g]	F	E. hemlock	S	15.51	284	211	74.3	20	7.0	49	17.3	4	1.4	28[e]
						Ties set 1928—20 years service								
Arsenious acid	F	Red oak	S	.47[j]	95	78	82.1	6	6.3	11	11.6			28[e]
Arsenious acid	F	Red oak	S	.27[j]	99	50	50.5	28	28.3	21	21.2			21[e]
C. t. creosote, grade 1[g]	F	Yel. birch	S	21.43	21	20	95.2			1	4.8			
Sodium dichromate	F	Red oak	H-S	.52[k]	96			89	92.7	6	6.3	1	1.0	6.8[m]
Sodium dichromate	F	Red oak	H-S	.27[k]	87			82	94.3	5	5.7			5.9
Zinc-meta-arsenite	F	Red oak	S	.50[n]	97	87	89.6	5	5.2	5	5.2			31[e]
Zinc-meta-arsenite	F	Red oak	S	.26[n]	111	65	60.4	26	23.4	18	14.4	2	1.8	23[e]
						Ties set 1929—19 years service								
C. t. creosote, grade 1[g]	E	Engl. spruce	H	6.67	48	32	66.7	12	25.0	3	6.2	1	2.1	23[e]
Natural brine	F	E. hemlock	S	16.70[o]	197	2	1.0	168	85.3	27	13.7			13[e]
Nickel chromate	F	Red oak	S	.50[p]	97			94	96.9	2	2.1	1	1.0	12.2[r]
Nickel chromate	F	Red oak	S	.25[p]	99	1	1.0	98	99.0					13[e]
Zinc chloride	E	Engl. spruce	H	1.07[c]	75	30	40.0	24	32.0	20	26.7	1	1.3	19[e]
Zinc chloride—C. t. creosote, grade 1[g]	T	Engl. spruce	H	.61[c] 8.36[q]	83	61	73.5	14	16.9	5	6.0	3	3.6	24[e]
						Ties set 1927 to 1929—19 to 21 years service								
Untreated	----	Corkbark fir	H-S	------	149	7	4.7	105	70.5	33	22.1	4	2.7	15[e]
						Ties set 1940—8 years service								
Untreated	----	Blackjack oak	S	------	23	11	47.8	9	39.1	3	13.1			8[e]
C. t. creosote, grade 1[g]	F, E	Blackjack oak	S	4.45[s]	69	66	95.6	2	2.9	1	1.5			
Zinc chloride	F	Blackjack oak	S	.32[c]	37	33	89.2	2	5.4	2	5.4			12[e]

Note: This test is being conducted in cooperation with the U. S. Forest Products Laboratory. For a detailed description of this test see "University Avenue Test Track at Madison, Wis.", page 136, Proceedings of the American Wood-Preservers' Association for 1935.

[1]F = full cell method.
E = empty cell method.
T = two-movement method.

[2]H = hewed ties; S = sawed ties; H-S = both hewed and sawed ties.

[3]Rail and plate cutting, splitting, crushing, etc.

[a]6% solution made by adding 6 gal. of concentrated Aczol solution furnished by Zinsser and Co. to each 94 gal. of water.

[b]Average based upon 90 ties removed and does not include those under crossings.

[c]Dry salt.

[d]Includes 2 white oak ties.

[e]Estimate—Based on U. S. Forest Products Laboratory tie renewal curve.

[f]Includes 4 white oak ties.

[g]A.W.P.A. specification.

[h]Petroleum.

[i]$Na_2B_4O_7.10H_2O$.

[j]Based on available A_2sO_3 in solution.

[k]$Na_2Cr_2O_72H_2O$.

[m]Average based on 95 ties removed and does not include one tie under crossing.

[n]Based on available $ZnAs_2O_4$ in solution.

[o]Estimated absorption of brine.

[p]Based on sum of nickel sulphate and sodium chromate in solution. The available nickel chromate constitutes 55.1% of the total weight of the two salts.

[q]Creosote.

[r]Average based upon 96 ties removed and does not include one under crossing.

[s]Based on 45 ties.

CONDITION OF THE EXPERIMENTAL TIES IN THE UNIVERSITY AVENUE TEST TRACK OF THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD AT MADISON, WIS. AT AN INSPECTION IN OCTOBER 1948

Preservative	Treating method[1]	Species	Form[2] of ties	Average absorption of preservative	Ties in test	Serviceable		Removed: Mainly for decay		Removed: Cause other than decay[3] and unknown causes		Not inspected (under crossings)		Average life
				Lb. per cu. ft.	No.	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Years
Ties set 1922—26 years service														
Aczol	F	Red oak	S	16.38[a]	95	—	—	90	94.7	—	—	5	5.3	12.2[b]
Zinc chloride (high iron content)	F	Red oak	S	.58[c]	87	—	—	39	44.8	48	55.2	—	—	14.0
Ties set 1923—25 years service														
25% low temp. c. t. distillate 75% mid continent oil	F	Red oak	H	8.22	100[d]	80	80.0	11	11.0	5	5.0	4	4.0	36[e]
50% low temp. c. t. distillate 50% mid continent oil	F	Red oak	H	9.24	98[f]	88	89.8	4	4.0	3	3.1	3	3.1	39[e]
Ties set 1924—24 years service														
C. t. creosote, grade 1[g]	F	Red oak	H-S	14.60	16	13	81.2	—	—	2	12.5	1	6.3	36[e]
Low temp. c. t. distillate	F	Red oak	H-S	8.94	84	65	77.4	7	8.3	11	13.1	1	1.2	32[e]
10% low temp. c. t. distillate 90% topped California oil	F	Red oak	H-S	8.94	99	79	79.8	7	7.1	13	13.1	—	—	32[e]
25% low temp. c. t. distillate 75% topped California oil	F	Red oak	H-S	8.28	100	71	71.0	16	16.0	13	13.0	—	—	30[e]
Ties set 1925—23 years service														
Basilit	F	Red oak	H-S	.28[c]	49	10	20.4	30	61.2	9	18.4	—	—	20[e]
10% c. t. creosote, grade 1[g] 90% petroleum	F	E. hemlock	S	10.26	87	66	75.9	11	12.6	10	11.5	—	—	30[e]
50% c. t. creosote, grade 1[g] 50% petroleum	F	E. hemlock	S	11.91	82	67	81.7	7	8.5	8	9.8	—	—	32[e]
Sodium fluoride	F	Red oak	H-S	.52[c]	50	15	30.0	28	56.0	7	14.0	—	—	22[e]
Sodium fluoride	F	Red oak	H-S	.26[c]	50	6	12.0	33	66.0	11	22.0	—	—	19[e]
Triolith	F	Red oak	H-S	.25[c]	50	14	28.0	24	48.0	12	24.0	—	—	21[e]
Zinc chloride	F	Red oak	H-S	.52[c]	50	2	4.0	40	80.0	8	16.0	—	—	17[e]
Zinc chloride	F	Red oak	H-S	.26[c]	50	1	2.0	41	82.0	8	16.0	—	—	16[e]
Zinc chloride—petroleum emulsion	E	Red oak	H	.34[c] 4.87[h]	49	18	36.7	19	38.8	12	24.5	—	—	22[e]
Zinc chloride—petroleum emulsion	E	So. yel. pine	H	.69[c] 9.21[h]	42	32	76.2	2	4.7	8	19.1	—	—	29[e]
Zinc chloride—petroleum emulsion	E	So. yel. pine	H	.39[c] 7.92[h]	49	42	85.7	3	6.1	4	8.2	—	—	34[e]
Zinc chloride—petroleum emulsion	E	So. yel. pine	H	.27[c] 9.34[h]	47	42	89.4	2	4.2	3	6.4	—	—	35[e]
Ties set 1926—22 years service														
Basilit	F	Red oak	H-S	.52[c]	49	23	47.0	18	36.7	8	16.3	—	—	23[e]
Basilit	F	E. hemlock	S	.18[c]	44	12	27.3	10	22.7	21	47.7	1	2.3	20[e]
Sodium fluoride	F	E. hemlock	S	.17[c]	49	12	24.5	17	34.7	20	40.8	—	—	20[e]
Triolith	F	Red oak	H-S	.56[c]	50	23	46.0	20	40.0	7	14.0	—	—	23[e]
Triolith	F	E. hemlock	S	.18[c]	48	12	25.0	16	33.3	20	41.7	—	—	20[e]

Creosote	Rueping	Flat	5.0	50	45	90.0	4	8.0	1	2.0	----------
Creosote	Rueping	None	5.7	50	30	60.0	11	22.0	9	18.0	41[e]
20% creosote, 80% zinc chloride	Card	None	15.5[f]	50	21	42.0	18	36.0	11	22.0	37[e]
20% creosote, 80% zinc chloride	Card	Flat	15.2[f]	50	35	70.0	12	24.0	3	6.0	44[e]
Semi-refined paraffin oil	Full cell	Flat	8.4	50	32	64.0	16	32.0	2	4.0	42[e]
Semi-refined paraffin oil	Full cell	None	6.2	49	12	24.5	31	63.3	6	12.2	33[e]
Zinc chloride-creosote	Two movement	Flat	14.7[g]	50	14	28.0	33	66.0	3	6.0	34[e]
Zinc chloride-creosote	Two movement	None	16.0[g]	50	9	18.0	34	68.0	7	14.0	31[e]
Zinc chloride	Burnett[c]	Flat	.50	206	-------	-------	188	91.3	18	8.7	19.2
Zinc chloride	Burnett[c]	Ribbed	.50	53	-------	-------	47	88.7	6	11.3	20.4
Zinc chloride	Burnett	None	.47	50	-------	-------	45	90.0	5	10.0	25.8
Zinc chloride	Burnett	Flat	.49	50	10	20.0	37	74.0	3	6.0	32[e]
Untreated		None	----------	50	-------	-------	50	100.0	-------	-------	8.7
Untreated		Flat	----------	50	-------	-------	50	100.0	-------	-------	9.2

Note: This test is being conducted in cooperation with the U. S. Forest Products Laboratory.

[a]Rail cutting, splitting, etc.

[b]Ties not available for examination after removal to determine the cause of removal.

[c]Obtained from regular stock of C. M. St. P. & P. RR.

[d]Steeping treatment in cold mercuric chloride solution—absorption figures not available.

[e]Estimate—Based on U. S. Forest Products Laboratory tie renewal curve.

[f]Emulsion of 80 parts of 3% zinc chloride solution and 20 parts of creosote by volume at approximately 70°F.

[g]3% zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3% zinc chloride solution.

Condition of Experimental Ties in the Chicago, Milwaukee, St. Paul & Pacific Railroad Test Track near Hartford, Wis., After About 36 Years Service

Ties set October, 1911

Preservative	Process	Tie plates	Average absorption	Ties in test	Condition of ties—1947: Serviceable		Removed: Mainly for decay		Removed: Mainly for causes other than decay[a] and unknown causes[b]		Average life
			Lb. per cu. ft.		Number	Percent	Number	Percent	Number	Percent	Years
			Chestnut								
Zinc chloride	Burnett[c]	Flat	.50	10			9	100.0	1	10.0	15.6
Zinc chloride	Burnett[c]	Ribbed	.50	13			7	53.8	6	46.2	13.4
			Spruce								
Mercuric chloride	Kyan	Flat	----[d]	13	1	7.7	12	92.3			29[e]
Mercuric chloride	Kyan	None	----[d]	12			11	91.7	1	8.3	21.8
			Maple								
Creosote	Full cell	None	10.7	50	48	96.0	2	4.0			
Creosote	Full cell	Flat	12.2	49	48	98.0	1	2.0			
Creosote	Rueping	Flat	5.0	50	47	94.0	3	6.0			
Creosote	Rueping	None	4.8	50	46	92.0	4	8.0			
20% creosote, 80% zinc chloride	Card	None	14.7[f]	50	42	84.0	8	16.0			50[e]
20% creosote, 80% zinc chloride	Card	Flat	17.3[f]	50	44	88.0	6	12.0			50[e]
Semi-refined paraffin oil	Full cell	Flat	11.1	50	42	84.0	5	10.0	3	6.0	50[e]
Semi-refined paraffin oil	Full cell	None	14.3	49	38	77.6	8	16.3	3	6.1	46[e]
Zinc chloride-creosote	Two movement	Flat	16.4[g]	50	24	48.0	22	44.0	4	8.0	38[e]
Zinc chloride-creosote	Two movement	None	15.1[g]	50	5	10.0	44	88.0	1	2.0	29[e]
Zinc chloride	Burnett	None	.50	49			34	69.4	15	30.6	19.0
Zinc chloride	Burnett	Flat	.50	50	11	22.0	35	70.0	4	8.0	32[e]
Untreated		None		50			50	100.0			6.4
Untreated		Flat		50			50	100.0			7.8
			Red Oak								
Creosote	Full cell	None	11.2	52	49	94.3	2	3.8	1	1.9	
Creosote	Full cell	Flat	10.9	50	44	88.0	3	6.0	3	6.0	

Report on Assignment 3

Destruction By Marine Organisms; Methods of Prevention

W. F. Clapp (chairman, subcommittee), W. P. Arnold, Walter Buehler, C. M. Burpee, F. W. Gottschalk, B. D. Howe, M. F. Jaeger, R. R. Poux, Hermann von Schrenk.

Tropical Timber Tests

It is most unfortunate that the tests on tropical timbers which have been conducted by Dr. James Zetek at Panama for many years were all lost during the war years. Dr. Zetek's last report on these tests was made in September 1943. This report was included in the Proceedings, Vol. 45, 1944, pages 284–288. Dr. Zetek has reported that since these tests were abandoned during the war, there will be no further reports.

Test Piles

The following five reports have been received from E. E. Mayo, chief engineer, Southern Pacific Company:

Report of Inspection on October 11, 1948 of Specimens Furnished by Chemical Warfare Service and Placed in San Francisco Bay at Request of Dr. Hermann von Schrenk

Gate 25–1–A installed at Biological Station, Oakland Pier, July 21, 1925. Removed 1942, replaced 1946. The untreated piece hung at this station shows heavy limnoria and light teredo attack.

No. 1 (1 percent ammoniacal copper carbontae)—Heavy limnoria and light teredo attack; removed from test.

No. 2 (Creosote and 1 percent diphenylamine chlorarsine)—Moderate limnoria attack.

Chemical Warfare Service Test Pieces Forwarded from Edgewood Arsenal by Lt. Col. E. C. Brigham and Hung at Oakland Pier, February 24, 1932; Removed 1942, Replaced 1946

Specimen	*Treatment and Retention*	*Condition*
A–11	Creosote 21.6 lb. per cu. ft.	Heavy limnoria attack around a knot and in heartwood on ends; very light elsewhere.
D–11	Creosote plus 2½ percent dinitrophenol 23.7 lb. per cu. ft.	Very light limnoria attack on sides; heavy attack in heartwood on ends.
E–11	Petroleum residuum plus 2½ percent dinitrophenol 22.5 lb. per cu. ft.	Heavy limnoria attack, some teredos.
F–11	Petroleum residuum plus 0.84 percent methyl arsenious oxide, 17.5 lb. per cu. ft.	Very heavy limnoria and teredo attack, 75 percent destroyed, removed from test.

Report of Inspection October 11, 1948 of Specimens Furnished Through Dr. Hermann von Schrenk and Col. W. G. Atwood and Installed in San Francisco Bay Area

Barrett Manufacturing Company Material placed at Station B, Pier 7, San Francisco, January 1923. Moved to Biological Station, Oakland Pier, Southern Pacific, December 1925. Removed 1942, replaced 1946. (P—Pine; F—Fir)

Condition of Experimental Ties in the Chicago, Milwaukee, St. Paul & Pacific Railroad Test Track Near the Fair Grounds, Madison, Wis.

Condition at 1948 inspection

Species	Preservative	Average absorption	Ties in test	Serviceable		Removed				Average life
						Mainly for decay		Mainly for causes other than decay[a] and unknown causes		
		Lb. per cu. ft.	No.	Number	Percent	Number	Percent	Number	Percent	Years
	Ties set 1916—31 years service									
Red oak	Zinc chloride	0.55	163			157	96.3	6	3.7	16.8
Red oak	25% creosote and 75% gas oil	10.20	75			31	41.4	44	58.6	25.9
Red oak	10% creosote and 90% gas oil	10.00	98	1	1.0	38	38.8	59	60.2	21[b]
White oak	Untreated		94			93	98.9	1	1.1	12.4
	Ties set 1917—30 years service									
Douglas-fir[c]	Creosote	11.50	28			4	14.3	24	85.7	23.7
Douglas-fir[c, d]	Untreated		38			36	94.7	2	5.3	6.5
Douglas-fir[c]	Untreated		47			37	78.7	10	21.3	13.3
Western larch	Untreated		44			43	97.7	1	2.3	10.7
Red oak	Sodium fluoride	.52	99			83	83.8	16	16.2	21.4
Red oak	Water gas tar	9.79	99	49	49.4	16	16.2	34	34.4	32[b]
	Ties set 1919—28 years service									
Douglas-fir[c]	Zinc chloride	.52	104			55	52.8	49	47.2	16.6
Western larch	Zinc chloride	.48	95			33	34.7	62	65.3	16.2
Red oak	50% c.t. creo. and 50% w.t. creo.	9.50	62	4	6.5	44	70.9	14	22.6	22[b]
Slippery elm	50% c.t. creo. and 50% w.t. creo.	10.85	25	2	8.0	7	28.0	16	64.0	22[b]
Butternut	50% c.t. creo. and 50% w.t. creo.	9.00	8			7	87.5	1	12.5	18.9
White oak	50% c.t. creo. and 50% w.t. creo.	7.30	1	1	100.0					
Cherry	50% c.t. creo. and 50% w.t. creo.	10.50	3			3	100.0			25.3
Red oak	Wood tar creosote	10.08	99			78	78.8	21	21.2	19.4
	Ties set 1921—26 years service									
Red oak	Low temperature coal tar oil	10.30	100	49	49.0	28	28.0	23	23.0	28[b]
Red oak	20% coal tar and 80% low temp. coal tar oil[e]	10.50	100	78	78.0	10	10.0	12	12.0	34[b]
Red oak	Vertical retort c.t. creosote	9.60	100	82	82.0	9	9.0	9	9.0	36[b]
Red oak	Pintsch gas tar	10.50	100	69	69.0	17	17.0	14	14.0	32[b]
	Ties set 1927—20 years service									
Jack pine	Zinc chloride	.52	379	14	3.7	345	91.0	20	5.3	15[b]

Note: This test is being conducted in cooperation with the U. S. Forest Products Laboratory.

[a]Rail cutting, splitting, etc.

[b]Estimate—Based on U. S. Forest Products Laboratory tie renewal curve.

[c]Western Washington and Oregon type.

[d]Switch ties.

[e]Reported as 50% tar and 50% low temp. coal tar oil prior to 1935.

TEST PILES, OAKLAND PIER, CALIF.

Turpentine wood piles driven December 1927 and January 1928 were inspected at extreme low tide on June 2, 1949. Of the 29 piles, 28 are still in service. All show very heavy limnoria attack, practically all of the sapwood having been eaten off. Pile No. 41 is now broken in two and out of the test.

In addition to the above 29, 10 other turpentine piles of the same age were not accessible for inspection. Of the original 50 piles, 4 have been lost by fire and 8 by breakage. None has failed from marine borer attack.

Testing Station, Almirante, Panama

In the Proceedings, Vol. 50, 1949, page 375, these pile tests were reported as having been lost. Twelve test timbers No. 432 have now been received by the United Fruit Co. Since this testing station is no longer being operated, the timbers have been forwarded to the laboratory at Duxbury, Mass., for examination. A summary of the report on the conditions, after approximately eight years exposure, of these timbers is as follows:

(For complete information regarding the treatment, etc. see AWPA Proceedings, 1942, pages 391 to 395, tables 8, 9, 10 and 11.)

A duplicate set was submerged at the Woods Hole test station.

A—Samples 3, 5, 9.—35 percent residue creosote. From 60 to 85 percent of surface with limnoria attack averaging ⅜ in. in depth. 50 exposed teredinidae tunnels per log. Preservative well leached from surface of logs.

B—Samples 23, 25, 29.—50 per cent of 35 percent residue creosote. 50 percent of 65 residue coal tar.

Samples 25 and 29 with about 10 percent or less of area with shallow limnoria attack. Few small teredinidae. Preservative well leached from surface.

Sample 23 and 45 percent of area attacked by limnoria to a depth of ¼ in. Few teredinidae.

C—Samples 31, 33, 37, 39.—20 percent residue creosote.

Practically 100 percent of surface with limnoria to a depth of ¾ in. to 1 in. Average of 100 exposed teredinidae tunnels. Preservative well leached from surface.

D—Samples 43, 49.—75 percent of 20 percent residue creosote. 25 percent of 65 percent residue coal tar.

Spotty attack averaging about 50 percent of surface attacked by limnoria to depth of ½ in. with some areas to a depth of 1 in.

Sample 43 with 60 exposed teredinidae, No. 49 with only a few.

Testing Station at Newport, R. I.

1. The original series consisted of 30 air-seasoned yellow pine logs, approximately 4 ft. long, average 8 in. in diameter, divided into three groups of ten specimens, as follows:

A—creosote; B—50/50 creosote-coal tar solution; C—coal tar.

The detailed characteristics of the samples were reported in AWPA Proceedings, Vol. 38, 1942 as an appendix to the report of Committee 7-4-1. See page 398, Table 14.

The samples have been submerged at Newport, R. I., since May 29, 1936, with the exception of 8 months after the 1938 hurricane. Inspections made in 1941 and 1947 revealed no evidence of marine borer attack. In August 1949 representative specimens were inspected.

A. Creosote—2 logs inspected. One had a few scattered limnoria.

B. Creosote—coal tar solution—2 logs inspected. No evidence of marine borers.

C. Coal tar—2 logs inspected. Few scattered limnoria over entire surface.

Gate	Specimen No.	Treatment	Condition October 10, 1947
B-4	P-1	Coke oven original oil	Moderate limnoria attack
	P-2	" " solids removed	" " "
	P-3	" " acids removed	Light limnoria attack
	P-4	" " bases removed	" " "
B-5	P-5	" " oil minus residue at 360° C.	Moderate limnoria attack
	P-6	" " " minus fraction 230–270° C.	Light limnoria attack
	P-7	" " " minus fraction up to 230° C.	" " "
	P-8	" " " minus fraction 270–360° C.	" " "
B-6	P-9	Vertical retort original oil	Light limnoria attack
	P-10	" minus solids	Moderate limnoria attack
	P-11	" minus acids	Light limnoria attack
	P-12	" minus bases	Moderate limnoria attack
B-7	P-13	" minus residue above 360° C.	Heavy limnoria attack
	P-14	" minus fraction 230–270° C.	" " "
	P-15	" minus fraction up to 230° C.	" " "
	P-16	" minus fraction 270–360° C.	" " "
B-8	F-1	Same as P-1	" " "
	F-2	Same as P-2	Light " "
	F-3	Same as P-3	" " "
	F-4	Same as P-4	" " "
B-9	F-5	Same as P-5	Moderate limnoria attack
	F-6	Same as P-6	Heavy localized attack
	F-7	Same as P-7	Light limnoria attack
	F-8	Same as P-8	" " "
B-10	F-9	Same as P-9	Heavy limnoria attack
	F-10	Same as P-10	" " "
	F-11	Same as P-11	Light " "
	F-12	Same as P-12	Moderate limnoria attack
B-11	F-13	Same as P-13	Heavy limnoria attack
	F-14	Same as P-14	Moderate limnoria attack
	F-15	Same as P-15	" " "
	F-16	Same as P-16	" " "

The untreated specimen at this station, 1947–1948, shows heavy limnoria and light teredo attack.
New test pieces have been added, treated with Hercules Powder Co. products, thanite and rosinamine D. Also pieces treated with cuprolignum and copper naphthenate.

Test Piles, Long Beach, Calif., January 24, 1949

Owing to the ground in this vicinity having settled, the tops of the piles are only about two feet above the water line at low tide, making it impractical to inspect the damaged portions of the piles.

Dock A, Pile 2	—driven November 24, 1925	Pile gone.
Dock A, Pile 7	" " " "	O. K.
Dock E, Pile 50	" " " "	Pile gone.
Dock A, Pile 33	" " " "	Poor, 40 percent eaten away, limnoria.
51	" " " "	Pile gone.
52	" " " "	Poor, 50 percent gone, limnoria.

At Ambrose lightship off New York harbor the tests submerged in June and removed in November were well filled with teredo *navalis,* many of which were eight inches in length.

At Diamond Shoals lightship the tests were filled with teredo (psiloteredo) *tryoni.*

At Nantucket lightship tests submerged on June 10, 1949 and removed on October 10 were riddled with three species of borers Some of the specimens were nine inches in length. The three species were teredo *navalis,* which is commonly found along the New England coast, teredo *megotara* which is a northern species found very plentifully and very destructive in Newfoundland and northern waters, and a species bankia closely related to, or possibly identical with, bankia (bankiella) *gouldi,* which is very plentiful and destructive from Virginia, south. Bankia *gouldi* has been reported as having been found rarely in New Jersey, but not from New York or New England. To find these three species which normally thrive in such widely different habitats is most unusual.

Since we now know that the borers exist in destructive numbers many miles at sea, it is possible that further studies in this field may indicate that by means of winds and currents the free swimming embryos may be carried from far off shore into previously uninfested areas along the coast. Sudden borer infestations in harbors which have been free from borers for many years may have come from this source rather than from borer infested drift wood as has previously been supposed.

Report on Assignment 4

Creosote–Petroleum Solutions

R. S. Belcher (chairman, subcommittee), Walter Buehler, H. B. Carpenter, W. R. Goodwin, R. P. Hughes, M. F. Jaeger, A. L. Kammerer, A. J. Loom, W. C. Reichow, F. S. Shinn, L. B. Shipley, J. E. Tiedt.

This report, which embodies a recommendation affecting the Manual, is a continuation of the report presented last year, Proceedings, Vol. 50, 1949, pages 377 to 379.

Your committee has given further study to the following phases of this assignment:

4. Specifications for petroleum for blending with creosote.
5. Specifications for creosote for blending with petroleum.
6. Specifications for various creosote-petroleum solutions that may be used for preservative treatment.
7. Methods of analysis of creosote-petroleum solutions that may be used for preservative treatment.

Under phase 6, your committee last year presented as information The Standard Volume Correction Table for Creosote-Petroleum Solutions, which appears in the Proceedings, Vol. 50, 1949, pages 378 and 379. The object was to give the members who make use of such a table an opportunity to try it for a year before it was presented for inclusion in the Manual. During the past year your committee has received no criticism or suggestion relative to this table, and it is now presented for adoption and inclusion in the Manual.

It is recommended that study of phases, 4, 5, 6 and 7 of Assignment 4 be continued.

2. The original series of 20 southern yellow pine logs, approximately 4 ft. long and 8 in. in diameter, divided into two groups of ten each, were treated as follows:

A—creosote with residue of 50 percent over 355 deg. C.
B—creosote with residue of 75 percent over 355 deg. C.

The detailed characteristics of the specimens may be found in AWPA Proceedings, Vol. 38, 1942, page 388, Table 3.

The logs were submerged at Newport, R. I. on April 1, 1940. An inspection made in 1941 showed no evidence of marine borer activity. In August 1949 representative logs were inspected with the following results:

A—50 percent residue—no evidence of marine borers.
B—75 percent residue—several patches of limnoria attack and few teredo.

Testing Station at Woods Hole, Mass.

Twelve pile sections approximately 4 ft. long and averaging 8 in. in diameter.

The 1949 inspection revealed the loss of the last three remaining pile sections in this series.

A series of 30 similar sections, treated to refusal with various solutions of coal tar and creosote, were submerged on June 1, 1942 (duplicates of Test 432 reported from Almirante above). These were inspected in August 1949 and several of the samples were found to be missing. No evidence of marine borer activity was noted in the remaining representative samples.

Test Board Studies

Test board studies are being continued along the New England coast by the New England Marine Piling Investigation Committee under the direction of S. G. Phillips, chief engineer of the Boston & Maine Railroad.

The New York Marine Piling Investigation is also being continued under the direction of Walter P. Hedden, director, Port of New York Authority.

Under the sponsorship of the Office of Naval Research, test board studies are being continued at the same locations as in previous years. In addition, test boards have now been submerged in Greenland and at all lightship stations in both the Atlantic and the Pacific. Special test boards have been submerged at 20 locations in the Caribbean by the United Fruit Company.

Standard test boards are now being operated at 325 locations.

During the season of 1948, teredo *dilatata* (teredo *megotara* Hanley) was found in destructive numbers at several locations along the coast of Massachusetts as reported in the AREA Proceedings for 1949.

In 1949 this species has again been found in the same harbors.

The tests submerged at most of the lightships have not as yet been removed from the water and returned to the laboratory.

It has been believed that the teredinidae would not occur in large numbers in the open sea. This group of borers requires wood in which to burrow, or some closely related material such as cordage. Far from shore it would seem that little material would be available into which these organisms could burrow.

It is therefore of considerable interest to note that the test board at Boston lightship, about 10 nautical miles off the coast of Boston, submerged on June 17 and removed on November 11, was well filled with teredo *megotara*. Many specimens had reached a length of eight inches.

Great Northern Railway Test

A carload of 393 7 by 9 red oak cross ties was received at the treating plant, relatively free of any surface checks. The ties were divided into four similar groups. Ties in Group 1 were taken directly from the car to the mill, were incised, bored and then stacked in normal 1 by 9 manner. The space between each tie was approximately ½ in. Group 2 ties were not incised or bored, but were stacked in the same manner as Group 1 ties. Group 3 ties were taken directly from the car, incised, bored and then stacked. Two-in. thick creosoted stickers were used in a manner similar to stringers at each end of each layer. The ties were stacked on edge. Group 4 ties were not incised or bored, but were stacked in the same manner as Group 3 ties. Each of the four groups of ties was placed in individual stacks on creosoted foundations in the treating plant yard for air seasoning.

One year later, or in July of 1949, ties were handled for tramming, at which time the face of each tie was carefully examined for season checks. The ties were graded into three groups—those having less than ⅛-in. checks, those having ⅛ to ¼-in. checks, and those having checks over ¼-in.

The following table summarizes the results:

Incised	*Checks less than ⅛ in.*	*Checks ⅛ to ¼ in.*	*Checks over ¼ in.*
Standard stack	95	3	1
Creoosote stack	98	2	0
	193	5	1

Unincised	*Checks less than ⅛ in.*	*Checks ⅛ to ¼ in.*	*Checks over ¼ in.*
Standard stack	90	6	1
Creosote stack	90	7	0
	180	13	1

Checking on the surfaces of incised ties was slightly less than that of unincised ties. There was no apparent difference between ties stacked on edge using 2-in. creosoted stickers and ties stacked in the normal 1 by 9 method. Just prior to treatment all ties which were not previously incised were incised and bored.

The treating schedule for the red oak ties was as follows:

Charge report No. 499	Koppers Company, Wood Pres. Div., Superior, Wis.
Date treated	July 8, 1949
Initial air	50 psi.
Pressure period	4 hours, 5 min. at 175 psi.
Temperature of oil	200 deg. F.
Final vacuum	22 in.
Preservative	50/50 creosote-petroleum solution

After treatment, all ties were spot installed between Floodwood and Wawena on the Great Northern ore line in Minnesota during July 1949. The ties which were not pre-incised have one 1949 date nail in the center of the top face. The ties which were pre-incised have two 1949 date nails on the gage end.

Ties in this test will be examined periodically during service to determine if pre-incising improves the service life.

Report on Assignment 6

New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products

F. W. Gottschalk (chairman, subcommittee), W. P. Arnold, R. S. Belcher, P. D. Brentlinger, H. B. Carpenter, W. F. Clapp, W. H. Fulweiler, F. A. Hartman, M. S. Hudson, N. E. Kittell, R. R. Poux, J. W. Reed, Henry Schmitz, Hermann von Schrenk.

This report, submitted as information, summarizes the progress which the subcommittee has made to date regarding new impregnants as well as what needs to be done in the future.

In way of review, last year's report included information and specifications for four new preservative impregnants; the salt-type preservatives, chromated zinc chloride and tanalith and the oil-type preservatives, pentachlorophenol and copper naphthenate. As a logical follow-up, the subcommittee should collect available service-record data on the new preservatives.

In addition, the subcommittee should study and report improvements made in existing preservatives such as the addition of copper compounds to chromated zinc chloride to make the new preservative known as copperized chromated zinc chloride; also, the development of any new petroleum solvents for pentachlorophenol and copper naphthenate. Likewise, service-record data on improved preservatives should be reported as it becomes available.

As other new preservatives are introduced the subcommittee will report full details as information. As a matter of interest, the 1949 Preservatives Committee of the American Wood-Preservers' Association report descriptions, properties, specifications, etc., for greensalt, and chemonite, which might also be studied by our committee.

Report on Assignment 7

Incising Forest Products

W. P. Arnold (chairman, subcommittee), F. W. Gottschalk, B. D. Howe, R. P. Hughes, A. J. Loom, C. H. Wakefield.

This is a progress report presented as information.

Effect of Incising on Checks and Splits in Mixed Hardwood Ties

Last year your committee submitted as information a report covering incising of mixed hardwoods, treatment and installation, by the Wheeling & Lake Erie Railway. These ties were inspected in August of 1949 and results of inspection revealed that the incised ties were still superior to the unincised ties and there were no appreciable changes over the past year. These inspections will be reported from time to time and when significant changes develop, detailed results will be given as information.

As a result of previous work on the incising of mixed hardwood ties, the Great Northern Railway and the Minneapolis, St. Paul & Sault Ste Marie Railway became interested in conducting similar tests on their respective railroads in Minnesota and Wisconsin. The tests were conducted in a manner similar to that described in the report last year.

Report on Assignment 11

Artificial Seasoning of Forest Products Prior to Treatment

W. P. Arnold (chairman, subcommittee), R. S. Belcher, P. D. Brentlinger, C. M. Burpee, R. F. Dreitzler, H. R. Duncan, F. W. Gottschalk, B. D. Howe, M. S. Hudson, R. R. Poux, L. B. Shipley, Hermann von Schrenk, F. S. Shinn.

Your committee submits as information the following report of progress on a study of preliminary conditioning:

Urea Impregnations for Retarding Checks in Beech and Hard Maple During Air Seasoning

In 1948 your committee submitted as information a report covering work by the Atchison, Topeka & Santa Fe Railway at Somerville, Texas, on the impregnation of red oak and southern pine cross ties, switch ties and timbers, with urea to determine its effect on subsequent seasoning with respect to checking and splitting.

As additional information to supplement that report, the following experimental data are submitted on hard maple and beech cross ties:

Six hard maple and six beech cross ties in a green condition were selected from cars in the treating plant. These ties were selected at random without regard to grade. Ties were selected green so as to eliminate the possibility of having any checks present.

Ties were taken to the mill where they were tagged and cut in half. Each parent tie was given two numbers. For example, 1 and 2 were numbers of halves of the first tie, 3 and 4 for the second tie, etc., through 23 and 24.

One half of each original parent tie was then treated with a 50-percent solution of urea by the following process in August 1944:

1. Cylinder filled with solution (Lowry).
2. Pressure period—½ hour.
3. Pressure—150 psi.
4. Temperature—room temperature.

Ties were removed from the treating cylinder, allowed to drain 30 min., weighed, and stacked for air seasoning along with matched controls. In November 1944, all ties were trammed and treated in the commercial cylinder, along with a commercial charge of hardwood cross ties. The treating cycle was as follows:

Charge report No. C–464	Koppers Company, Wood Pres. Div., Orville, Ohio
Initial air	80 psi.
Pressure period	4½ hours
Pressure	200 psi.
Treating temperature	210 deg. F.
Final vacuum	22 in.
Preservative	50/50 creosote-coal tar solution

The table shows retentions of urea and 50/50 creosote-coal tar solution, and penetrations after preservation treatment of the beech and maple ties.

Ties were inspected at various intervals for surface appearance. Those treated with urea had fewer and less severe checks than the controls, when inspected prior to treatment with 50/50 creosote-coal tar solutions. However, both the controls and those pre-

Minneapolis, St. Paul & Sault Ste Marie Railway Test

A carload of 500 6 by 8 beech and hard maple ties was received in the treating plant and the ties were placed in four similar groups. The ties in Group 1 were taken directly from the car to the mill, were incised, adzed and bored and then stacked in a normal 1 by 9 manner. The space between each tie was approximately ½ in. Group 2 ties were not incised, adzed or bored, but were stacked in the same manner as Group 1 ties. Group 3 ties were taken directly from the car, incised, adzed and bored, then stacked. Two-inch thick creosoted stickers were used in a manner similar to stringers at each end of each layer. The ties were stacked on edge. Group 4 ties were not incised, adzed or bored, but were stacked in the same manner as Group 3 ties. Each of the four groups of ties was placed in individual stacks on creosoted foundations in the treating plant yard.

At the time ties were handled for tramming, 1 year later in July 1949, the face of each tie was carefully examined for season checks. The ties were graded into three groups—those having less than ⅛-in. checks, those having ⅛ to ¼-in. checks, and those having checks over ¼-in.

The following table shows the results:

	Checks less than ⅛ in.	*Checks ⅛ to ¼ in.*	*Checks over ¼ in.*
Incised			
Standard stack	93	22	10
Creosote stack	86	30	9
	179	52	19
Unincised			
Standard stack	74	38	13
Creosote stack	69	46	10
	143	84	23

The data show that there were fewer serious checks (those ⅛ in. to ¼ in. and those over ¼ in.) in the incised ties than in the unincised ties. There was no apparent difference between ties stacked on edge using 2-in. creosoted stickers and ties stacked in a normal 1 by 9 method. Just prior to treatment all ties which were not previously incised were incised, adzed and bored.

These ties were treated by the following cycle:

Charge report No. 496	Koppers Company, Wood Pres. Div., Superior, Wis.
Date treated	July 8, 1949
Initial air	40 psi.
Pressure period	4 hours, 5 min. at 175 psi.
Temperature of oil	200 deg. F.
Final vacuum	23 in.
Preservative	50/50 creosote-petroleum solution

These ties were installed out of face in the Minneapolis–Duluth Line between Frederick and Lewis, Wis., west from the culvert at M. P. 75.69. The ties which were not pre-incised are the first 250 west of the culvert, followed in a westerly direction by the 250 pre-incised ties. Each of the ties in the test has two 1949 date nails in it.

All ties in this test will be examined periodically during service to determine if pre-incising improves the service life.

Based on this study the following information is offered:

(a) It is not possible to reduce the moisture content of 4 by 8-in. southern yellow pine timbers from a green state to below 20 percent moisture content within 24 hours.

(b) A steep moisture gradient is set up within the wood which causes more than a tolerable amount of surface and internal checking and severe case hardening.

(c) The most effective drying takes place within the first 12 hours.

(d) The absorption of drying oil limits the use of this process as a conditioning method for material which is to be treated with either oil or water soluble salt preservatives.

While the sponsor of this process feels that lumber and timbers can be adequately seasoned by this process, it is believed that considerable difficulty will be encountered by the inexperienced operator and further, that this process is not wholly satisfactory for conditioning lumber from a green to a dry state.

At the present time, it is understood that this process is being used only to dry salt-treated lumber.

RETENTIONS AND PENETRATIONS OBTAINED IN UREA TREATMENT

BEECH

Half Tie No.	*Dry Urea lb./cu. ft.*	*Ret. 50/50 Pretreated With Urea*	*CCTS lb./cu. ft. Controls*	*Penetration Pretreated With Urea*	*50/50 CCTS In. Controls*
1	1.12	2.4		.14	
2			3.8		.56
3	4.60	2.2		.12	
4			3.2		.38
5	1.36	3.2		.07	
6			4.0		.90
7	1.65	2.4		.05	
8			3.7		.36
9	2.68	3.4		.24	
10			3.8		.51
11	1.13	2.4		.20	
12			3.2		.20
Average	2.09	2.7	3.6	.14	.49
MAPLE					
13	1.45	4.9		.08	
14			9.5		.31
15			7.4		.42
16	.95	6.8		.35	
17	5.90	2.7		.06	
18			9.9		.51
19	.86	7.0		.32	
20			8.1		.61
21			8.2		.44
22	1.67	5.3		.17	
23	1.12	6.8		.24	
24			8.3		.38
Average	1.99	5.6	8.6	.20	.45

treated with urea have been laid flat in the plant yard for the past five years and recent examination disclosed that there was no appreciable difference in the condition of ties, regardless of preseasoning handling.

Report on Drying of Wood in Oil Solutions

In 1948 a report was submitted as information regarding a process of drying wood in oil by the Wood Dryers, Inc., Charlotte, N. C. At the time of the report the process was still in the experimental development stage; however, since that time some experimental work has been conducted by another company to attempt to duplicate the claims made by the Wood Dryers, Inc.

In this experimental work four pieces of 4 by 8 by 6-ft., S4S, southern yellow pine in green condition, were processed for 6, 12, 16, and 24 hours, in the special drying oil recommended by the Wood Dryers, Inc., at a temperature of 240 deg. F. Cross sections of these pieces were cut at periodic intervals during processing for the purpose of determining moisture content and percent of drying oil absorbed.

Report of Committee 8—Masonry

C. B. Porter, *Chairman,*
G. C. Ashton
M. W. Bruns
E. E. Burch
J. R. Burkey
L. T. Casson
H. C. Charlton
C. C. Cooke
G. H. Dayett
H. J. Engel
J. A. Erskine
J. U. Estes
A. B. Fowler
W. P. Geiser
R. W. Gilmore
J. F. Halpin
J. S. Hancock
R. Hayes
Meyer Hirschthal
A. C. Johnson
J. E. Kalinka
A. P. Kouba
J. A. Lahmer
A. N. Laird
F. W. Lincoln
R. F. M. Marshall
R. L. Mays
E. A. McLeod
G. A. McRoberts
L. M. Morris
M. Nearing
L. H. Needham
M. S. Norris
Roscoe Owen
D. B. Packard
G. H. Paris
R. E. Paulson
R. B. Peck
H. Posner
W. R. Prass
W. R. Wilson, *Vice-Chairman,*
R. V. Proctor
J. L. Rippey
Louis Rossman
E. T. Rucker
C. P. Schantz
Everett Scroggie
C. M. Segraves
J. H. Shieber
D. H. Shoemaker
F. R. Smith
L. Spalding
Neil Van Eenam
Jamison Vawter
K. J. Wagoner
C. A. Whipple
W. Wilbur
V. E. Williams
E. P. Wright

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Principles of design of masonry structures, collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30.

   No report.

3. Foundations for masonry structures, collaborating with Committees 1, 6, 7, 15 and 30.

   No report.

4. Earth pressure as related to masonry structures.

   No report.

5. Methods of designing, constructing and maintaining tunnels, collaborating with Committees 1, 5, 28 and 29.

   No report.

6. Methods of repairing masonry, including internal pressure grouting.

   Report on methods of repairing and solidifying masonry structures presented for adoption and publication in the Manual .... page 364

7. Methods for improving the quality of concrete and mortars, collaborating with Committee 6.

   Report on influence of aggregate characteristics on proportioning of concrete, presented as information .... page 372

AREA Bulletin 485, January 1950.

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Report of Committee 29—Waterproofing

R. L. Mays, *Chairman,*
Lyle Bristow
R. A. M. Deal
L. J. Deno
L. P. Drew
P. R. Eastes
E. T. Franzen
Nelson Handsaker
W. G. Harding
W. H. Hoar
E. A. Johnson
M. L. Johnson
J. A. Lahmer
J. F. Marsh
M. S. Norris
B. J. Ornburn
H. A. Pasman
F. J. Pitcher
T. M. von Sprecken, *Vice-Chairman,*
W. E. Robey
G. E. Robinson
Henry Seitz
A. L. Sparks
V. G. Tellis
J. P. Walton
C. A. Whipple

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Waterproofing of railway structures, collaborating with Committees 8 and 15.

   No report.

3. Waterproofing protection to prevent concrete deterioration.

   Progress report, presented as information below.

The Committee on Waterproofing,
R. L. Mays, *Chairman.*

Report on Assignment 3

Waterproofing Protection to Prevent Concrete Deterioration
Collaborating with Committees 8 and 15

Under a contract with the AAR, Purdue University completed a laboratory test, during 1949, on the relative effectiveness of surface waterproofing coatings. This is the first phase of a series of tests contemplated and involved experimental work on 65 surface coatings supplied by manufacturers.

These tests consisted of the manufacture of three concrete test specimens and three control specimens for each coating to be tested. After manufacture and proper curing, the test specimens were coated with the waterproofing paints in accordance with the manufacturers' directions and were subjected to 72 hours' immersion in water. The control specimens without waterproofing were subjected to the same immersion, and the relative absorption of the average of the three coated specimens and the average of the three uncoated or control specimens were determined by weighing them.

The specimens were then placed in a weatherometer and exposed to carbon-arc light for 150 hours and again subjected to the 72-hour immersion test, after which they were weighed. A comparison of the two immersion tests before and after the weatherometer test provided a means of evaluating the durability of the paints.

The next step was the freeze and thaw test under which the specimens were alternately frozen to —18 deg. F. and thawed at 130 deg. F. for 50 cycles, after which the specimens were again subjected to the 72-hour immersion test. Decrease in moisture content indicated by weighing afforded a measure of resistance to weathering.

It is proposed to augment these tests, which will be covered in a later report, with outdoor weathering tests.

Bulletin 484, December 1949.

Recognizing the timely interest in and the importance of these specifications, and after careful consideration of the comments and suggestions received on this subject, your committee offers the following specifications for adoption and publication in the Manual to replace material on pages 8–141 to 8–142, inclusive.

REPAIRING AND SOLIDIFYING MASONRY STRUCTURES

A. GENERAL

1. Scope

These specifications apply to repairing of deteriorated masonry by patching, encasement and pressure grouting. For shotcrete repairs, see separate specifications for shotcrete.

Engineering plans should be made when strengthening of the structure is involved.

2. Preliminary Work

Conditions causing or contributing to deterioration, including faulty drainage, shall be corrected where practicable. Existing drains shall be cleaned and otherwise put in working order. New drains shall be installed where required.

If impracticable to correct inadequate drainage and thus prevent saturation, the part of the structure so exposed shall be made watertight by replacing honeycombed and unusually porous portions and/or by filling cracks and pores with pressure grout or waterproofing materials, all of which are subject to the approval of the engineer.

The effectiveness of existing expansion joints shall not be impaired.

3. Materials

The materials used shall conform in physical properties to AREA Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures, except as hereinafter specified. Air-entraining cement may be used if approved by the engineer.

The color of the aggregate and cement for patching or partial encasement shall be selected to produce a color as nearly the same as practicable as that of the old concrete.

Sand used in hand-patched concrete shall preferably have a "fineness modulus" between 2.80 and 3.

Sand used for pressure grout shall be plaster sand, fine mason sand or engine sand; the fineness modulus shall not be more than 2.

Wire mesh shall be composed of cold drawn steel wire, electrically welded and galvanized.

And bonding, waterproofing or counter shrinkage material used shall be approved by the engineer.

All special equipment for placing concrete or grout shall be an approved type.

B. SURFACE REPAIR

1. Scope

Repairs shall consist of removal of soft, disintegrated or honeycombed concrete or stone, cleaning and preparing the bonding surface, placing of anchor bolts and reinforcing, placing of concrete by shotcreting, handpatching, or pouring, or as specified, and finishing such concrete to true lines and surface and proper curing.

8. Specifications for the construction and maintenance of masonry structures.
Report on guide to water cement ratio method of making concrete, presented as information .... page 389

THE COMMITTEE ON MASONRY,
C. B. PORTER, *Chairman.*

Karl R. Beck

Karl R. Beck, chief masonry inspector on the Illinois Central Railroad, a member of Committee 8—Masonry, died on April 7, 1949.

Mr. Beck was born at Merigold, Miss., on July 23, 1891, and was graduated from the University of Mississippi in 1914, with a Bachelor's Degree in Civil Engineering. He entered the employ of the Illinois Central in August 1915, as a rodman, and except for 18 months' service with the 512th Engineers during the First World War, served that railroad continuously until his death.

In 1948, Mr. Beck became a member of the American Raliway Engineering Association, and was appointed to membership on Committee 8—Masonry, early in 1949.

A pleasing personality, and a conscientious devotion to his duties won for Mr. Beck the esteem and respect of his associates on the railroad and on the committee. His passing is recorded with deep regret.

William Morrison Ray

William Morrison Ray, retired senior assistant engineer, Baltimore & Ohio Railroad, died on November 5, 1949. Mr. Ray was born on June 11, 1869 at New Philadelphia, Ohio and entered railway service with the Cleveland, Lorain & Wheeling Railway in 1893, after being graduated from Ohio State University. His service with the B. & O. began in 1902 and was continued without interruption until his retirement in 1940.

He joined the Association in 1917 and rendered valuable service as a member of the Committe on Masonry for 19 years. Mr. Ray was a loyal and devoted friend and an untiring worker and the Committee on Masonry takes this opportunity to record the deep sense of loss occasioned by his death.

Report on Assignment 6

Methods of Repairing Masonry, Including Internal Pressure Grouting

C. P. Schantz (chairman, subcommittee), L. T. Casson, R. W. Gilmore, J. S. Hancock, R. Hayes, R. F. M. Marshall, L. H. Needham, D. B. Packard, J. L. Rippey, F. R. Smith.

Tentative specifications for repairing and solidifying masonry structures were submitted, as information in 1948. They appear in the Proceedings, Vol. 50, 1948, pages 314–320 incl. The specifications were submitted so that the Association would have an opportunity to review and criticise them before they were offered for adoption and publication in the Manual.

Specified spacing of anchors is based on supporting three times the total weight of suspended concrete and two times the weight of concrete on vertical surfaces. Facilities shall be provided for testing the supporting value of anchors. Each anchor shall be set in sound masonry as specified in the table below and shall be capable of supporting, without loosening, the suspended load indicated.

Dia. of Bolt–In.	*Min. Embedment–In.*	*Load in Lb.*
¼	1½	150
⅜	2⅜	400
½	2⅝	750
⅝	3¼	1,200
¾	4	1,750

Any anchor failing to support such load shall be reset.

Where concrete 4 in. or more in thickness is to be placed, approved anchors shall be set where shown on the plans, or in accordance with the following table:

SIZE AND SPACING OF ANCHORS

Thickness of Concrete In.	*Suspended Concrete In Dia. at Ft.–In.*	*Vertical Surfaces In. Dia. at Ft.–In.*	*Top Surfaces In. Dia. at Ft.–In.*
4	⅜ @ 1–8	⅜ @ 2–0	⅜ @ 3–0
5	" @ 1–5	" @ 1–9	" @ 3–0
6	" @ 1–4	" @ 1–8	" @ 3–0
7	" @ 1–2	" @ 1–6	" @ 3–0
8	½ @ 1–7	½ @ 1–11	½ @ 3–0
9	" @ 1–6	" @ 1–10	" @ 3–0
10	" @ 1–5	" @ 1–9	" @ 2–0
11	" @ 1–4	" @ 1–8	" @ 2–0
12	" @ 1–3	" @ 1–6	" @ 2–0

Where the thickness of concrete is more than 8 in., the anchors shall be dowels. Where the thickness of concrete exceeds 12 in., the size, length, spacing and embedment of dowels shall be determined or approved by the engineer.

The exposed end of each anchor shall have a right angle, or greater, bend for engaging reinforcement.

No isolated area greater than 2 sq. ft. shall have fewer than three anchors.

Where only a single line of anchors is required, the maximum spacing shall be 24 in. and the size shall be determined in accordance with second paragraph under Anchorage.

Dowels shall be made of deformed bars, shall be grouted in and shall be long enough to engage a mass of masonry sufficient to support the load. Horizontal dowel holes shall be drilled downward on a slope of approximately one inch per foot.

4. Reinforcement

Where new concrete 4 in. or less in thickness is to be placed, one layer of 3 in. by 3 in. by No. 10 or 2 in. by 2 in. by No. 12 gage wire mesh shall be secured to the anchor bolts.

Vertical and Top Surfaces. Where new concrete over 4 in. in thickness is to be placed, one layer of wire mesh shall be used for each 4-in. thickness, or fraction thereof, secured to the anchors.

Suspended Surfaces. Where new concrete 3 in. thick or more is to be suspended, one additional layer of wire mesh shall be used for each additional 3-in. thickness, or fraction thereof. Each layer of mesh shall be wired to each anchor.

2. Preparation

All loose, soft, honeycombed and disintegrated concrete or stone shall be removed from the areas to be repaired by means of power and hand tools, to expose a bonding surface of sound material.

Thin or feathered edges shall be avoided and the boundries of the areas to be repaired shall be square cut or slightly undercut to a depth of not less than one inch.

Abrupt changes in the thickness of concrete patches shall be avoided.

All defective construction joints and detrimental cracks in concrete shall be chipped out to a minimum of 4 in. in width by 2 in. in depth.

Structural cracks or joints, where movement in the structure, by reason of expansion, contraction or vibration is apparent, shall be sealed by means of 10-in., 16 oz. cold rolled copper expansion plates preformed along the longitudinal center line of the copper to produce a modified "V" shape, 1 in. high and ½ in. open, having rounded bends. The concrete or stone shall be chipped out sufficiently to provide space for installation of a water-tight joint between the copper and concrete and also for a channel for water seepage, properly drained at the base of crack or joint. (Fig. 1)

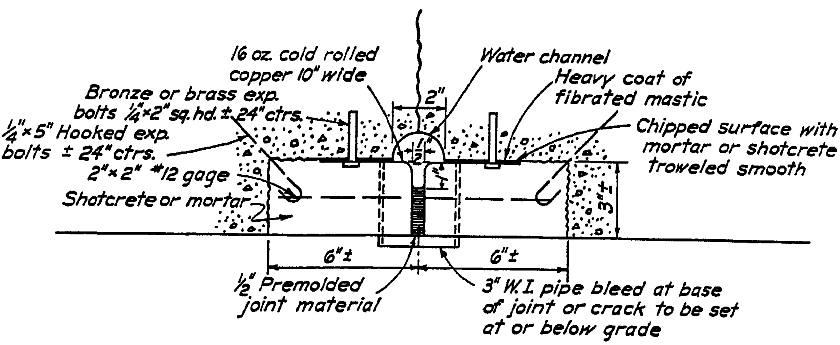

Fig. 1.—Repair of Joints or Cracks Where Movement Occurs in the Structure.

The expansion joint between the finished surface and "V" of the copper plate shall be filled with a ½ in. thick strip of premoulded asphaltic expansion joint material. The patch shall be reinforced and placed as hereinafter specified.

On concrete masonry, removal shall not exceed 8 in. in depth, except as specified or directed by the engineer.

The bonding surface should be rough, clean, sound concrete or stone. Oil or film of any sort that may reduce the bond shall not be permitted. Loose particles of dust and dirt shall be removed by wire brushes, sandblast, or air, followed, finally, by water blast.

3. Anchorage

Where new concrete less than 4 in. thick is to be placed, ¼-in. dia. galvanized expansion hook bolts shall be spaced 18 in. center to center on vertical surfaces and 12 in. center to center on overhead surfaces. Each bolt shall have sufficient engagement in the sound masonry to resist a pull of 150 lb. When pried from the wall with a bar inserted under the bend of the bolt, the bend shall straighten without pulling the bolt.

intervals of about 10 min. to prevent drying out and hardening on the surface of the pile. After the shrinkage period, when the concrete is ready to be placed, it should be of such consistency that it will just hold together when tightly squeezed in the hands.

After the surfaces of the cavity have been prepared as specified above, the retempered mortar or concrete shall be placed and thoroughly rammed in thin layers into the forms, using every effort to secure intimate contact between the old and new concrete. The ramming should continue until the top surfaces are moist, but in no case should the concrete contain enough water for the ramming to produce a plastic or mushy mass.

Where restoration or encasement is accomplished by ramming the new concrete in between forms and the old surface, the forms shall have sufficient strength to withstand the pressure of the new concrete without yielding appreciably. The new concrete shall completely fill the space provided and present a surface identical with the original. Vibration of the forms in lieu of ramming is subject to approval of the engineer. Vibrators, if used, shall preferably deliver not less than 3000 impulses per minute.

The surface finish shall conform with that on adjacent old concrete unless otherwise required by plans or the engineer.

6. Curing and Protection

The surface of all new concrete shall be kept thoroughly wet for a period of at least seven days, beginning immediately after placement.

An approved curing compound may be used in lieu of the above.

Repair work shall not be done in freezing weather unless properly protected, nor until the old structure is free from frost. The new concrete shall have a temperature when placed of not less than 50 deg. F., nor more than 120 F., and shall be kept at a temperature not lower than 50 deg. F. for not less than 72 hours after placing, or until the concrete has thoroughly hardened.

C. INTERNAL CONSOLIDATION

1. Scope

Internal consolidation by pressure grouting consists of filling voids, seams and cracks in masonry, with grout containing cement and water, and, if required by the engineer, other ingredients such as fine sand, waterproofing agents, countershrinkage materials and admixtures to improve penetration.

2. Preparation

Before the grouting operation is started, all defective materials are to be removed and the entire surface of the masonry shall be thoroughly inspected for points of leakage and indications of voids. Inserts for grouting shall be so located and set that the pressure grout will reach all voids and paths of leakage.

All defective exposed joints and cracks in disintegrated masonry shall be chipped out with power tools, then thoroughly cleaned of all foreign materials by means of high pressure air or water blast.

The joints, cracks and disintegrated areas shall be restored to the original surface with hand pointing or shotcrete consisting of one part of cement, three parts of sand and, if required by the engineer, an approved type of countershrinkage material.

Where surface joints or cracks are small, it may be desirable to allow them to remain open until the internal grouting operation is completed in order to release any trapped air between the interior of the joints and the surface.

A two-way system of ¼-in. dia. reinforcing bars securely wired to anchors shall be provided for vertical and suspended surfaces. The last layer of mesh shall be continuous, except over expansion joints, and shall be secured by wiring to the reinforcing bars.

All reinforcement involved in the repair work shall be completely embedded in the new concrete and shall be not less than 1½ in. from the finished surface of the concrete. Each layer of mesh must be completely encased before the succeeding layer of mesh is applied. The succeeding layer of mesh shall not be applied until the previous layer of encasement has set. Reinforcement shall be held away from the surface of the older concrete.

Reinforcement extending around corners or re-entrant angles shall be bent to a templet before securing to anchorage and not sprung or forced into position. At corners, double reinforcing mesh shall be provided and extended a minimum distance of 6 in. beyond the intersection of the two planes.

Splice bars shall lap at least 20 dia. of the bar, with laps securely wired together. Where splices of wire mesh are necessary, a lap of one mesh shall be required, wired together at intervals of not more than 18 in.

Where special reinforcement is required for structural strength, engineering plans will be furnished. Reinforcement in the old structure shall be thoroughly cleaned and any deficiency in area shall be supplied with additional reinforcement.

5. Placement

After the bonding surfaces of the old masonry have been prepared as outlined in paragraph B 2, and where new concrete is to be placed by hand-patch methods, the bonding surface shall be kept constantly wet for a minimum of one hour immediately prior to application of the bonding or waterproofing coat. In no case shall fresh materials be applied to a dry surface. The bonding or waterproofing coat shall be applied to the damp bonding surface and shall be vigorously brushed on to completely fill all surface pores immediately prior to placing the body of the new concrete. The bonding coat shall be composed of cement or one part cement to one part fine sand and sufficient water to make a creamy mixture. If required by the engineer, an approved waterproofing or countershrinkage material shall be added. The bonding coat shall not be troweled, screeded or disturbed before the next layer of new concrete is applied.

Immediately after bonding coat has been applied, the entire cavity shall be filled to finished lines with retempered mortar or concrete, composed of 1 part cement to 2½ parts of sand. Proportions may be increased to 1 part cement to 5 parts graded aggregates where cavities are deeper than 1½ in. The concrete shall be thoroughly impacted. In the case of overhead, steep, or vertical surfaces, the concrete shall be placed in successive layers, but while preceding concrete is still green. In any case, where it is necessary to permit any concrete to harden, any new applications of concrete shall be applied over a new bonding coat.

Each morning all concrete placed the previous day shall be sounded for adhesion and soundness. All areas which fail to meet the test shall be cut out and replaced.

Retempered mortar or concrete shall be used for hand patching concrete. After the predetermined quantities of cement, sand, coarse aggregate and water are mixed thoroughly to a uniform consistency so that the initially mixed concrete will stand in a cone with slopes of about 60 deg. with the horizontal without slumping, it shall be protected from the sun and allowed to stand for a period to be determined by the engineer, varying from 50 min. to 1 hour and 15 min. During this interval the mass shall be remixed at

5. Grouting

(a) *Stone Masonry.*—Grout shall be applied by pneumatic, pump. or gravity pressure.

Grout inserts shall be set in drilled holes and the interior voids washed clean with water, prior to the application of the pressure grout.

The grout shall be forced into the internal voids and joints of the structure, by means of pneumatic or hydraulic pressure to fill all internal voids completely and consolidate the masonry.

Grouting shall be started at the lowest row of holes and at the hole nearest the center line of structure.

If grout appears in adjacent holes at the same elevation, these holes shall be temporarily plugged and grouting continued in the original hole until grout appears at the next adjacent hole at the same elevation or at the next line of holes above the one being grouted. When this condition occurs, grouting of the original hole shall be discontinued and the grout line moved to the last hole at the lowest elevation at which grout appeared, and the same procedure followed until all holes in the lowest line have been grouted, at which time grouting shall proceed in a like manner along the next line of holes above, etc., until the entire structure has been completely filled.

During the course of all grouting operations, extreme care shall be given to observing the surrounding ground, track subgrade, ballast and the stream bed for the breaking out of grout, and when such breaking out occurs, the grout line shall be moved to some other part of structure. Grouting may be resumed in the original location after the elapse of 24 hours.

In grouting foundations, pressure grout should be applied to the various holes in rotation, keeping a careful watch of the surrounding ground, including the water in the stream. When grout breaks out in either the ground or stream, all operations should be suspended until the next day, at which time new holes are drilled and the same procedure followed until the grout again breaks out, which will usually be at a higher level than on the preceding day.

The above program should be followed until the grout is brought up into the masonry.

(b) *Concrete.*—Concrete shall be similarly grouted by pneumatic pressure or pressure pumping through inserts set in holes, to completely fill and seal all internal voids intercepted.

6. Cleaning

On completion of, and during progress of, the pressure grout operations, all excess deposits occurring over the exposed masonry face shall be cleaned off. Exposed surfaces of stone masonry shall be cleaned by sand blasting if required by the engineer.

The work shall be conducted in such a manner that, when the job is completed, it will have a workmanlike appearance.

3. Grout Holes—Drilling

(a) *Stone.*—Before drilling of the grout holes is started, test drillings shall be made through the masonry to the back of the same and to the bottom of the footings in order to detremine the thickness of the masonry. From these test drillings, the proper depth of grout holes shall be determined in order that grout holes shall not be drilled completely through the masonry.

Grout holes shall be drilled at substantially regular intervals, e.g., at 10-ft. spacing horizontally and 2½-ft. spacing vertically, staggered to include approximately 25 sq. ft of surface area per hole or at such other locations as may be specified. Holes shall be 1½ in. min. dia. and shall be drilled to such a depth, and in such manner, as necessary to intercept joints and internal voids, so that complete consolidation of the structure is assured. No holes which have been drilled completely through the masonry shall be used for pressure grouting and these holes must be completely plugged before grouting begins.

In cases of arch rings, the holes shall be drilled diagonally to intercept the longitudinal joints (parallel to the barrel) and staggered at such intervals as to include approximately 12 sq. ft. of surface area per hole.

On structures, or parts of structures, of one stone thickness, the grout holes shall be drilled in such a manner as to intercept the horizontal joints where possible; however, if, due to insufficient clearance, these holes cannot be drilled through the horizontal joints, they shall then be drilled so as to intercept the vertical joints.

The holes in the courses of masonry below ground line shall be drilled diagonally downward at various angles, but not into the foundation below the masonry, so that consolidation of the bottom courses is assured.

In case of masonry which is founded on a timber grillage which it is desired to consolidate, diagonal holes at various angles should be drilled through the timber to the natural foundation so that consolidation of the timber grillage is assured.

(b) *Concrete.*—Following the removal of all loose, disintegrated or otherwise defective concrete, the entire exposed surfaces of the structure shall be carefully inspected for points of seepage, internal honeycombed areas, cracks or voids, and where located 1½-in. grout holes shall be drilled therein to a sufficient depth and spacing as necessary to assure maximum effectiveness of these for the dissemination of the pressure grout throughout these areas.

Prior to pressure grouting, the chipped areas shall be restored as hereinbefore specified, provisions being made to extend the grout holes through the replacement material for grouting after the exposed surfaces are so sealed.

4. Grout

(a) *For Stone Masonry.*—Generally, the pressure grout mixture shall consist of 1 part of cement, ½ part of sand (see paragraph A 3) and, if required by the engineer, an approved type of countershrinkage material.

The amount of sand to be used in the grouting mixture shall be determined by starting the grouting operation with neat cement grout and adding sand in gradually increasing proportions until the optimum ratio of sand to cement has been reached which will give a free flowing grout. If it is found through application of the above that the addition of sand retards the free flow of the grouting material, the sand shall be omitted.

(b) *For Concrete.*—Generally, the pressure grout shall consist of neat cement grout only, and, if required by the engineer, an approved type of countershrinkage material.

Present-day methods of mix design are usually based on the fineness-modulus theory, the surface area of aggregate, or the absolute-volume principle, or a combination of these methods. By the fineness-modulus theory, the ratio of fine to coarse aggregate is determined by the fineness or coarseness of the materials to be combined in the mixture. By the surface-area method, the amount of cement and water required to coat the grains of fine aggregate and the amount of cement, sand, and water necessary to coat the particles of coarse aggregate are determined. The absolute-volume theory uses the relation of absolute volume of concrete ingredients to a unit volum of concrete—with the absolute volume of cement, plus the absolute volume of aggregate, plus the volume of water, totalled to equal "one." Another ratio used in the absolute-volume method of mix design is the ratio of the absolute volume of coarse aggregate in a unit volume of concrete to of absolute volume of concrete ingredients to a unit volume of concrete—with the absolute This method of proportioning is based on the theory that a definite quantity of mortar over and above that required to fill the voids in the coarse aggregate is necessary for workability, and that this mortar is made up of a combination of cement, water, and sand. It has been said that the approach to the theory of the design of concrete mixes can be simplified by concentrating on the idea of a mixture of graded solid particles and water, and considering the cement temporarly as an inert powder, completely ignoring its active properties.

Types of Aggregates

Natural Aggregates

The natural fine aggregate most commonly used is river sand, or bank sand, a fine, granular material resulting from the natural disintegration of rock, or from the crushing of friable sandstone rocks. Another fine aggregate, not so widely used, is stone screenings, which is a material obtained in the process of crushing stone for coarse aggregate. The natural coarse aggregates include: rounded gravel, a coarse granular material resulting from the erosion of rock by natural agencies; crushed gravel, the product resulting from the artificial crushing of gravel; and, crushed stone, the product resulting from the artificial crushing of rocks, boulders, or cobblestones.

Manufactured Aggregates

Manufactured fine aggregate, which is rarely used, consists principally of a fine material resulting from the crushing of blast-furnace slag and is known as "slag sand." The most commonly-used manufactured coarse aggregate is crushed blast-furnace slag, which is the nonmetallic product resulting from the crushing of blast-furnace slag (consisting essentially of silicates and alumino-silicates of lime, and of other bases) which is developed simultaneously with iron in the blast furnace. Another manufactured coarse aggregate is obtained by crushing burned clay.

Aggregates to be used in concrete should meet the requirements of the current ASTM Standard Specifications for Concrete Aggregates, designation C 33.

Characteristics of Individual Aggregate Particles

The principal characteristics of aggregate particles influencing the proportioning of concrete mixtures are: Particle shape and size, surface characteristics, and specific gravity.

The shape of fine aggregate particles does not vary appreciably, being either worn smooth by water or sharp as a result of crushing. The coarse aggregate particles may be thin, flat, elongated, round or angular, or a combination of those shapes. It is inter-

Report on Assignment 7

Methods for Improving the Quality of Concrete and Mortars

Collaborating with Committee 6

M. S. Norris (chairman, subcommittee), W. M. Bruns, J. F. Halpin, J. A. Lahmer, L. M. Morris, G. H. Paris.

This report is the result of considerable study and research and should be of interest to those concerned with the manufacture and control of concrete. Your committee presents, as information, the following report on the influence of aggregate characteristics on the proportioning of concrete.

The Influence of Aggregate Characteristics on the Proportioning of Concrete

Introduction

The purpose of this report is to summarize the physical characteristics of aggregates and their effect on the proportioning of concrete, and to present, for the guidance of those engaged in the design of concrete mixtures, information concerning the various properties of the more commonly-used aggregates.

The influence of aggregates on the properties of concrete mixes is controlled by maximum size, grading, particle shape, surface texture, and other characteristics. The aggregate in a concrete mixture is usually measured by weight (dry or surface dry) or by volume (either damp and loose, or dry and compact). When measured by weight the proportions of aggregate are expressed in terms of pounds of aggregate per sack (94 lb.) of cement. Such mixes are usually expressed as a specified number of pounds of fine aggregate and a specified number of pounds of coarse aggregate, per sack of cement. When measured by volume the proportions of aggregate are expressed in terms of cubic feet of each aggregate for each cubic foot of cement—with a sack of cement weighing 94 lb. net being taken as one cubic foot. An example is the familiar 1:2:4 mix consisting of one part cement, two parts sand, or other fine aggregate, and four parts gravel, stone, slag, or other coarse aggregate.

During the past 60 years in which concrete has been developed as a structural material, the methods of determining the amount of aggregate in a concrete mixture have ranged from the earliest rule-of-thumb methods to the scientific theories adopted for use on nearly all concrete construction today. Early methods of proportioning included: Gallons of water to equal the volume of sand plus the volume of stone, the aggregate to be measured in cubic feet of loose volume, with the sack of cement taken as "one" in the ratio of cement to aggregate. By another early method, the weight of dry materials was divided as 15 percent cement, 25 percent sand, and 60 percent gravel. Certain methods of proportioning by volume used a container of known capacity, filled with coarse aggregate and water, to determine the amount of paste required to fill the voids in the coarse aggregate. Early specifications stated that the volume of fine aggregate shall be not less than 30 percent nor more than 42 percent of the sum of the fine and coarse aggregates. Another method of proportioning concrete mixtures used an assumed weight of 4000 lb. per cu. yd. of concrete and deducted the weight of cement and water (determined by using sacks of cement per cubic yard, with a water-cement ratio) to obtain the total weight of aggregate per cubic yard of concrete.

Voids

The voids in a volume of an aggregate are the spaces between the individual particles of material, and are usually expressed in terms of a percentage of the total volume. The voids are usually determined by a method which takes into consideration the specific gravity and unit weight. The amount of voids in a given volume of aggregate is affected by the particle size, gradation, and physical characteristics of the material; and the percentage of voids may be expressed with the aggregate in a dry-loose, damp-loose, dry-compact, dry-rodded, or inundated condition. The current ASTM Method of Test for Voids in Aggregate for Concrete, designation C 30, provides a method for determining voids in aggregates.

Optimum Grading

For each aggregate or combination of aggregates of a given maximum size, an optimum gradation exists which will provide the highest workability in concrete, when the water-cement ratio is constant. Departure from optimum gradation toward either finer or coarser gradings will require a greater amount of water to maintain equal workability. The distribution of particle sizes in a natural aggregate never conforms to the ideal grading for that material, and will rarely be acceptable without some corrections. The correction of grading deficiencies within reasonable limits makes for greater economy in mix design resulting in a lower cement requirement, but usually increases the initial cost because of processing costs and wastage.

Fineness Modulus

The fineness modulus of an aggregate may be considered an abstract number, obtained by adding the total percentages of a sample of the aggregate retained on each of a specified series of standard sieves and dividing the sum of 100. The fineness modulus and surface modulus are not comparable in mixed aggregates of varying gradation. In aggregates having the same fineness modulus, one may have six times the surface area of another. Using a constant fineness modulus of mixed and fine aggregates, the percentage of fine aggregate in the mix increases as the fineness modulus of the coarse aggregate increases; whereas, with a constant fineness modulus of mixed and coarse aggregates, the percentage of fine aggregate in the mix increases as the fineness modulus of the fine aggregate increases. For a constant fineness modulus of fine and coarse aggregates, the percentage of fine aggregate in the mix increases as the fineness modulus of the mixed aggregate decreases. The fineness modulus serves its purpose best when used only as a measure of average fineness of an aggregate.

Surface Modulus

The surface modulus of an aggregate is an empirical constant, which is a function of the square of the diameter of the aggregate particles. It can be calculated from the sieve analysis, and expressed as a percentage of the weight of the material between two adjacent sieves. Surface modulus, which has no formal ASTM status in the grading of aggregates, is large for fine materials and small for coarse materials. Fine aggregate in which coarse particles predominate has less total grain surface in a unit volume than fine aggregate made up of fine particles.

Amount of Fines

The fines in an aggregate are those particles which will pass through a No. 200 sieve. A method for determining the amount of fines is given in the current ASTM Standard Method of Test for Amount of Material Finer than No. 200 Sieve in Aggregates, designation C 117.

esting to note that, considering the importance of particle shape, there is no existing standard test for determining the shape of aggregate particles as compared with the standard tests for determining the other characteristics and quality of concrete aggregates. Consequently, particle shape is determined only by visual inspection, although this characteristic of aggregates must be taken into consideration in the design of concrete mixtures.

The size of fine-aggregate particles ranges from dust to ⅜ in. Coarse-aggregate particles range from ⅜ in. to large rubble, and very large particles are classed according to diameter measurement. Particles of both fine and coarse aggregates are classified in the commercial sizes by passing them through standard sieves.

The surface of aggregate particles may be rough or smooth. The roughness is due to cellular structure, with the degree of roughness varying with the number and size of cells. Uncrushed gravel has a smooth particle surface, while crushed gravel, stone, and blast-furnace slag have rough particle surfaces. The aggregates with a rough surface texture have a larger surface area per unit of volume than is usual in rounded aggregates. This fact becomes evident when particles of uncrushed gravel are compared with particles of slag aggregate. There is no standard specification covering the surface texture of aggregates, and there appears to be no need for one.

The specific gravity of both fine aggregate and coarse aggregate is expressed in terms of apparent specific gravity or bulk specific gravity. The latter is the value generally used in the design of concrete mixtures, and is of vital importance in determining the proper proportions and yield of concrete when aggregates are being proportioned by weight. The procedure for determining the specific gravity of aggregate is given in the current ASTM Standard Method of Test for Specific Gravity and Absorption of Fine Aggregate, designation C 128, and the current ASTM Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate, designation C 127. The bulk specific gravity, on either a dry or saturated surface-dry basis, is used to compute the bulk volume of aggregate in the concrete. Aggregates for use in concrete vary in specific gravity from 2 for the lightweight slags to 3 for the heavier traprocks. Coarse aggregate with a specific gravity under 2.5 may contain particles which are porous, soft, and highly absorptive.

Characteristics of Combined Aggregate Particles

Gradation

Sieve analysis has long been the accepted technique for the measurement of grading of aggregates; the results of which are given as percentage passing each sieve, percentage retained on each sieve, or percentage retained between consecutive sieves. The analogy of aggregate particles to graded spheres evolves mathematical relationships between the amounts of successive sizes that permit them to form a relatively solid pack without particle interference. The fact that particles are not spheres and do not take assumed positions has to be allowed for in grading constants.

Certain characteristics of an aggregate may be judged from a sieve analysis, and a grading chart is useful for depicting the size distribution of aggregate particles. The sieve analysis of fine and coarse aggregates, and combinations of the two, gives important information on the concrete-making properties of materials. The current ASTM Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates, designation C 136 covers sieve analysis procedure.

tionable, in that they are deficient in cohesion and cannot properly support the larger sizes of aggregate particles which settle in the mix, become concentrated, and cause particle interference. Any grading of sand in which one or two particle sizes predominate should be avoided, as such sand has a large void content and requires a large amount of water-cement paste to produce a workable mixture.

For every maximum size and for every grading of a given coarse aggregate, there is a limiting amount that can be added to a given mortar without producing unworkability. Ideal gradation of the percentage type may be defined as a condition where the amount of material retained on each successively smaller sieve is a fixed percentage of that preceding. A desirable grading is that which just produces a workable mix while preserving a density somewhat less than the maximum possible. If the optimum amount of sand is used, with a proper water ratio, a satisfactory mixture can be made without special effort in grading the aggregate. The advantages of good grading should be understood fully by the mix designer, who is primarily responsible for the quality of the concrete in its plastic state. The permissible tolerance of undersize or oversize material in each designated size of aggregate should not exceed 10 percent. Many theories have been proposed for obtaining an ideal grading for aggregates; but it is generally accepted that an ideal grading depends on the type of aggregate, the degree of workability desired, the amount of cement in the mixture, and the water-cement ratio specified.

Particle Interference

Particle interference may be described as the wedging of aggregate particles against one another in such a way as to interfere with the workability of the mixture. Particle interference occurs in a mixture: First, when the amount of cement-water paste is not sufficient to fill the voids in the fine aggregate and coat the aggregate particles sufficiently to prevent direct contact between the particles; and, second, when the absolute volume of water, cement, and fine aggregate does not sufficiently exceed the voids in the coarse aggregate to prevent direct contact between the particles. The roughness of the surfaces of particles increases internal friction in fresh concrete.

Shape of Particles

The shape of aggregate particles affects the workability and density of concrete and the proportions of materials that can be used, especially in lean mixes. Long, slivery, and flat particles are harsh working, requiring more paste and more fine aggregate to produce workable concrete; and, as a result, they require more cement than rounded particles. An aggregate composed of smooth, rounded particles may give satisfactory results with coarser grading than would be permitted for an aggregate made up of sharp and angular particles with rough surfaces. The amount of aggregates in a mixture will vary, depending on the shape of the coarse-aggregate particle. Coarse aggregates of identical grading, having rough surfaces and made up of angular-shaped particles will not produce as smooth and workable a concrete mixture as aggregates having smooth, rounded particles when mixed with the same amount of mortar of the same consistency. To avoid harshness when a crushed-stone aggregate is used, a larger proportion of sand is required than when a gravel aggregate is used. Particles of sand or gravel which are round offer an advantage in yield, since more aggregate of given general grading can be used in the mixture without increasing the water-cement ratio. Stone screenings, because of the roughness and splintery shape of the particles, to produce a given consistency, require more cement paste than natural sands, and usually require special crushing for economy in cement requirement.

Unit Weight

The unit weight of aggregate is the weight of a given volume of material graded as it is to be used in the concrete mixture, in a stated degree of compactness and moisture, such a dry-loose. damp-loose, dry-compact, or dry-rodded. The bulking of fine aggregates —which is due to looseness of measure, moisture content, and size of particles—increases the volume as much as 30 percent, while coarse aggregates are affected very little in volume by moisture. The unit weight of aggregate is determined by the current ASTM Standard Method of Test for Unit Weight of Aggregate, designation C 29.

Absolute Volume

The absolute volume of an aggregate is the actual total vloume of solid material in all of the particles. The absolute volume of particles in a given volumetric measure varies inversely with bulking and directly with density. An absolute basis of proportioning concrete mixtures must include the absolute volume of the aggregate particles.

Density

The density of a fine or coarse aggregate or a combination of aggregates is determined by the amount of voids or space between the particles. An excess of particles ot approximately the same size will appreciably decrease the density of the aggregate.

Effect of Aggregate on the Design of Mixes

Aggregate Grading

One of the chief problems in designing concrete mixtures is the selection and proportioning of various sizes of aggregate particles, for the best economy in a mixture having the necessary workability with the specified water-cement ratio. The favorable grading of aggregate serves two important functions: First, to contribute to uniformity and workability of the plastic mixture; and, second, to reduce the quantity of cement required to produce concrete of a given quality.

Gradings finer than those recommended are likely to be uneconomical, requiring an unusually high cement factor because of greater water requirement for workability; and those much coarser are likely to be too harsh for satisfactory workability. If the fine aggregate approaches the limit of fineness, the coarse aggregate may approach the limit of coarseness with less danger of unworkability than otherwise. Aggregates graded up to large sizes require less paste to coat them and fill the spaces between the particles, than aggregates of smaller size and, consequently, are more economical. A large aggregate particle broken into several smaller pieces exposes new surfaces which must be coated with paste—yet the volume of aggregate has not been increased. Either very fine or very coarse sand or aggregate having a large deficiency or excess of any size fraction is undesirable for concrete. Allowable grading limits for sand depend to some extent on the shape and surface characteristics of the particles. It is desirable to use the lowest proportion of fine aggregate which will slightly more than fill the voids in the coarse aggregate. The fine aggregate should not contain more than 35 percent of any one size when separated by standard sieves. There is normally no lower limit on the size of aggregate, but quantities of fine material are limited in accordance with grading tolerances.

Gap grading is the omission of most or all of one or more of the size classes. Some authorities recommend gap gradings as having some advantages over continuous gradation of sizes from fine to coarse. The benefit is believed to accrue from a reduction in wedging action by omission of intermediate sizes. The benefits, however, are still controversial, and inadequately explored. Most authorities agree gap gradings are objec-

of fine to coarse aggregate is equal to a certain fineness modulus only as long as the fine and coarse aggregates do not vary in gradation. In general, somewhat more fine aggregate and less coarse aggregate must be used with crushed materials than with rounded materials, in order to provide comparable workability. The recommended ratio of the fine aggregate to the total aggregate (on the basis of dry, compact volumes measured separately) ranges from 45 percent to 50 percent for ¾ in. maximum size of coarse aggregate, and from 30 percent to 50 percent for 1 in. and over maximum size of coarse aggregate. Crushed aggregate requires relatively more fine material to compensate for the sharp, angular shape of the particles. In both lean and rich mixtures, the percentage of fine aggregate by weight of total aggregate averages 3 percent more with angular aggregate than with rounded aggregate for a coarse aggregate, with a maximum size range between ¾ in. and 3 in. Blast-furnace slag aggregate tends to give harsher mixes than rounded aggregate, on account of the rougher surface of the slag particles and higher void-percentage; but this can be overcome by the use of a higher ratio of fine to coarse aggregate than is required with rounded aggregates.

The larger the maximum size of a graded aggregate, the greater is the yield that can be secured for a given water-cement ratio, as each large-size fragment, which is without paste, replaces mortar and other fragments of smaller size having paste between them. For aggregates of larger size, the water requirement per unit volume of concrete becomes less, because of the reduction in surface area of the aggregate, giving a corresponding reduction in the amount of paste required.

It has been determined that the amount of mixing-water required for a given consistency decreases as the maximum size of aggregate increases, and as the proportion of coarse to fine aggregate increases. The percentage of voids directly affects the proportion of fine to coarse aggregate; and, to secure a satisfactory concrete, it is necessary to take this fact into consideration when designing mixes. Two aggregates may have exactly the same specific gravity and grading, but be quite different in unit weight and void content, due to a difference in the shape of the particles of which they are composed.

These things should all be given due consideration in the design of concrete mixes, especially with reference to the proportion of fine to coarse aggregate. Harshness occurs in mixes which are undersanded. However, the amount of sand used in the mix exerts a great influence on the water content, and it should be held as low as possible consistent with the demands of workability. The best proportion of fine and coarse aggregate is not necessarily the densest mixed aggregate. Mixtures of aggregates which give the greatest density when dry do not necessarily give the greatest density when mixed with cement and water. An economical mixture may usually be obtained by using a volume of cement equal to 1 to 1½ times the voids in the sand, and a volume of mortar equal to 1 to 1½ times the voids in the coarse aggregate.

The percentage of sand, as well as its fineness and the maximum size of particles has a definite influence on water requirements. The percentage of sand necessary to produce a workable concrete depends on its grading and the shape and surface characteristics of the particles. In the gradation of sand, each increase of 0.1 in fineness modulus of a well-graded sand increases the required sand percentage by 1. Thus there is required about 3 percent less of a fine sand, and 3 percent more of a coarse sand than of a medium sand. Each reduction of the water-cement ratio of ½ gal. of water per sack of cement permits the percentage of sand to be reduced by 1. A medium consistency requires 1 percent less sand than either a stiff or wet consistency. In the comparison of crushed stone versus gravel when the water-cement ratio is fixed, the optimum percentage

It will be noted from Table 1 that, when the sand and water contents, per cubic yard of concrete, of mixes using angular coarse aggregate are compared with mixtures using rounded coarse aggregate, the mixes using angular coarse-aggregate required 5 percent more sand and 3 gal. more water per cubic yard of concrete for the same maximum size of coarse aggregate. The mixtures in Table 1 had the same slump and water-cement ratio.

TABLE 1.—APPROXIMATE SAND AND WATER CONTENTS PER CUBIC YARD OF CONCRETE*

Maximum Size of Coarse Aggregate In.	Rounded Coarse Aggregate: Sand Percent of Total Aggregate by Absolute Volume	Rounded Coarse Aggregate: Net Water Content Per Cu Yd. Lb	Rounded Coarse Aggregate: Net Water Content Per Cu Yd. Gal.	Angular Coarse Aggregate: Sand Percent of Total Aggregate by Absolute Volume	Angular Coarse Aggregate: Net Water Content Per Cu Yd Lb	Angular Coarse Aggregate: Net Water Content Per Cu Yd Gal.
½	51	335	41	56	360	44
¾	46	310	37	51	335	40
1	41	300	36	46	325	39
1½	37	280	34	42	305	37
2	34	265	32	39	290	35
3	31	250	30	36	275	33
6	26	220	26	31	245	29

* Adapted from Table No. 5—Recommended Practice for the Design of Concrete Mixes. ACI Mix Design Standards. 613–44.

Note: The above table is based on aggregates of average grading and physical characteristics in mixes having a W/C of about 0.57 by weight or 6½ gal. per sack of cement, 3-in. slump, and natural sand having a F. M. of about 2.75.

The figures in Table 2, which show the effect of particle shape on water requirement in mixtures, indicate that lower water-cement ratios may be used with rounded coarse-aggregate, when the cement content is held constant.

TABLE 2.—EFFECT OF AGGREGATE-PARTICLE SHAPE ON WATER REQUIREMENT IN CONCRETE MIXTURES HAVING CONSTANT CEMENT CONTENT*

Sacks of Cement per cu yd. Concrete	Uncrushed Gravel: Water Gal./Sack Cement	Uncrushed Gravel: W/C by Volume	Slag or Stone Aggregate: Water Gal./Sack Cement	Slag or Stone Aggregate: W/C by Volume
4.0	9.0	1.20	10.0	1.34
4.5	7.9	1.06	8.9	1.19
5.0	7.1	0.95	7.8	1.04
5.5	6.4	0.86	7.0	0.94
6.0	5.8	0.78	6.3	0.84
6.3	5.5	0.74	6.0	0.80
6.5	5.3	0.71	5.8	0.77
7.0	4.9	0.66	5.2	0.70

* Adapted from Tables XII and XVI of "Materials Required Per Cubic Yard of Slag, Stone and Gravel Concrete and Cement Mortar," by Fred Hubbard, National Slag Association. 1940.

Proportion of Fine Aggregate to Coarse Aggregate

The significant relation of aggregate grading to the proportioning of concrete mixtures makes it necessary to consider the combinations of fine and coarse aggregates. A properly-proportioned combination of fine and coarse aggregates contains all sizes between the smallest and the largest, without an excessive amount of any one size. A ratio

2 percent material passing the No. 100 sieve and not less than 10 percent material passing the No. 50 sieve. The smaller particles of fine aggregate constitute a highly significant part of a concrete mixture, because of the great influence which small particles exert on the water and cement requirement and the workability of concrete. Very fine aggregate adds to the mobility of the mixture, increases the water requirement, and functions as a diluent to the cement. Dust is a diluent or extender of cement, not a component part of the fine aggregate. Silt or other inert particles finer than the cement-particle size adulterate the cement, and reduce the density of the mixture. All fine aggregate should contain a sufficient quantity of fine particles to assist the cement in producing good workability.

Cement Requirement

Greater economy in cement requirement and higher quality in concrete may be obtained by using aggregate of the largest practicable maximum size. The grading of the coarse aggregate may be varied considerably without affecting the cement requirement for a given water-cement ratio and workability, provided the optimum amount of fine aggregate is held constant. By increasing the maximum size of aggregate so as to extend the range over which the particles are graded, the total amount of aggregate that can be used with a given cement paste may be increased. Fine sand will require more cement for a given water-cement ratio and slump than a coarser-graded material. The optimum percentage of sand for a concrete mixture is the quantity which will result in the lowest water content and provide the required workability. When the optimum amount of sand (whether fine or coarse) is used, there is little difference in cement rquirement in a mixture. For a given water-cement ratio, the mixture requiring the lowest water content will also require the least cement, as over-wet mixes require high cement factors. Coarse sand has less total grain-surface in a unit volume—which means less cement, with the same amount of voids. Gradings finer than certain limits are likely to be uneconomical; and those much coarser are likely to be too harsh for satisfactory workability. Aggregates of approximately the same specific-gravity combination which gives the maximum unit weight dry will also give approximately the highest yield of concrete for a given quantity of cement.

TABLE 3.—EFFECT OF GRADATION OF COARSE AGGREGATE ON CEMENT REQUIREMENT*

Composition of Coarse Aggregate Percent by Weight			*Optimum** Amount of Sand*	*Cement Required at Percent Sand Indicated Sacks per Cu. Yd*	
No. 4 to 3/8 In	*3/8 to 3/4 In.*	*3/4 to 1 1/2 In*	*Percent*	*Optimum*	*35 Percent*
35.0	00.0	65.0	40	5.4	5.7
30.0	17.5	52.5	41	5.4	5.8
25.0	30.0	45.0	41	5.4	6.2
20.0	48.0	32.0	41	5.4	6.0
00.0	40.0	60.0	46	5.4	7.0

* Adapted from Table 1—"Concrete Information—Influence of Aggregate Characteristics on Proportioning Concrete." PCA No. ST 38, Second Edition.

** Amount giving best workability with aggregates used.

Note: The above table is based on a water content of 6.3 gal. per sack of cement.

Table 3 gives the results of tests in which the same grading of sand was used throughout, but the grading of the coarse aggregate was varied, with the maximum size

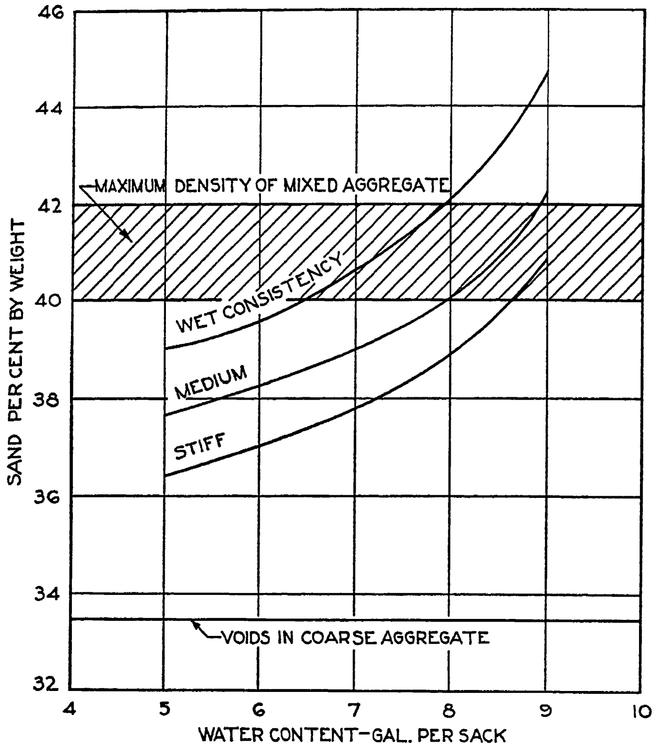

Fig. 1.—Relation of Sand Requirement to Water Content of Paste for Concrete Mixtures Having Different Degrees of Workability.

of sand is about 3 percent higher for crushed stone than for gravel, and is about 3 percent higher for stone sand than for natural sand. When the cement content is fixed, corresponding values are five and five. The optimum percentage of sand is practically always below the percentage for maximum density of mixed aggregate.

Fig. 1 gives the relationships among the percentage of sand, the water-content of the paste, and the workability of the concrete mixtures. The gradings of the sand and coarse aggregate were the same in all of the tests, and the maximum size of coarse aggregate was 1½ in. The curves, each representing a different degree of workability, indicate the proportions of sand which required the least quantity of cement paste; and the cross-hatched area represents the proportion of sand which gave the maximum density of mixed aggregate. It will be noted that the optimum percentage of sand departs considerably from this percentage for mixtures of low water-cement ratio and for the stiffer consistencies. The percentage of sand will usually be less when the sand is fine than when it is coarse.

Amount of Fines

Beach or plaster sands, which are classed as very fine sands, when combined with coarse aggregate produce a mixture which segregates easily—and, for that reason, are objectionable in a concrete mixture. It is important that sand contain not less than

With a given cement content and degree of workability, it is necessary to vary the water-cement ratio when aggregate is changed in particle shape from rounded to angular.

Porosity of Aggregate

The amount of water which will be contributed to or absorbed from a concrete mixture, by the aggregates, is dependent upon the porosity of the aggregate particles. Aggregates which are "saturated and surface dry" do not contain free moisture and will not absorb water from the mixture. When aggregates are not used in a saturated and surface-dry condition, free water carried by the aggregates must be taken into consideration in the water required for the water-cement ratio. A concrete mixture contains approximately 1 part water, 2 parts cement, and 10 parts aggregate, by weight. Therefore, a variation of 1 percent in the weight of the aggregate due to change in the moisture content will cause a variation of 10 percent in the water-cement ratio of the concrete. From this, it can be seen that the variation in the water-cement ratio will be considerable, with the moisture content of the aggregates not controlled within three or four percent by weight, as is the case on the average concrete-construction work.

Amount of Paste

One of the fundamental and highly-important conceptions in the proportioning of concrete for plasticity and workability is that a film thickness of mortar must exist around the coarse-aggregate particles to keep them sufficiently separated, so that they can move relative to one another. This can be accomplished by using the right volume of dry-rodded coarse aggregate in a unit volume of concrete. The lower the water-cement ratio and the stiffer the paste, the thicker the coating and the more paste needed. With the same water-cement ratio, paste in excess of that required to coat aggregate has no value, and affects the economy of the mixture. Coarse aggregate has a pronounced influence upon the economy of the paste because of its greater relative volume and replacement capacity at a nearly constant ratio of water to cement. The conventional concept of concrete as a water-cement paste diluted with hard, inert particles is essentially correct. The substitution of cement for fine sand does not appreciably affect the density of the mixture. The total water content per unit volume of concrete required to provide equal consistency with given aggregates varies with the paste content, and must be increased as the mixtures become richer. In specifications where the proportions of aggregate are specified either by weight or by volume, the amount of mortar in each mixture of concrete must be sufficient for workability, when an angular coarse aggregate of the highest permissible fineness modulus is used in the mixture. Such a condition results in an excess of mortar when a rounded coarse aggregate is used and, therefore, the mix is not economical in yield. It has been found that rounded and angular aggregates of the same specific gravity and same percentage of voids, when used in a concrete mixture, will require different amounts of mortar for the same degree of workability.

The effect of sand content on the paste requirement is shown in Fig. 3. For any given workability, the proper amount of sand varies with the water content of the paste. There is an optimum amount of sand which, for a given degree of workability, will require the least paste. Smaller or greater percentages than the optimum will require more paste as indicated in Fig. 3, where the relationship of paste content to the percent of sand is shown. The curve shown is for concrete of medium consistency. Points on the curve to the left of the optimum represent mixes which would be too harsh unless additional cement paste were used. Points to the right of the optimum represent mixes that would be too stiff due to the increased sand—and, again, additional paste is required to maintain the workability.

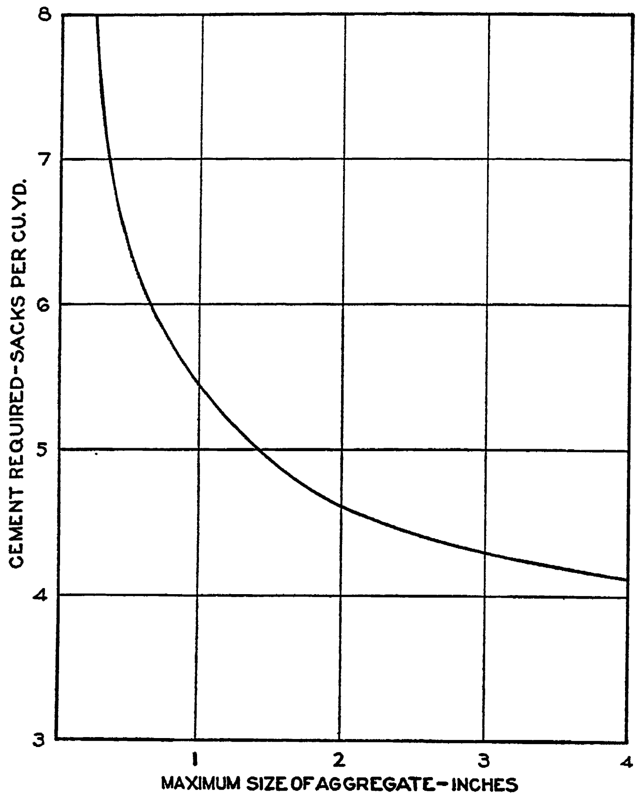

Fig. 2.—Effect of Maximum Size of Aggregate on Cement Requirement for Concrete of 3 to 5-In. Slump and 6½ Gal. Mixing Water per Sack of Cement.

of coarse aggregate being 1½ in. in each case. A constant water-cement ratio and degree of workability were used. It will be noted from the table that the cement requirement did not vary when the optimum amount of sand was used; when 35 percent (an arbitrary percentage of sand) was used, the cement content varied 1.3 sacks of cement per cu. yd. of concrete; and, in all cases, a lower cement factor was required when the optimum amount of sand was used. When a constant cement factor is used, the optimum amount of sand will produce a mixture requiring the least amount of water for a given consistency.

Fig. 2 shows the influence of the size of the aggregate on the cement content of concrete of a given slump and quality of paste. It will be noted that there is a marked economy in cement as the maximum size of aggregate is increased up to about 3 in. For a specified cement content and water-cement ratio, a definite amount of aggregate, both fine and coarse, is required to provide a mixture of the desired mobility. Any desired workability and uniformity of mixture may be obtained by the use of an excess of cement and fines, provided the water content is controlled. However, good workability with a low cement content can only be secured with carefully-graded aggregate.

Amount of Voids in Aggregate

The voids in an aggregate are a very important factor in determining proper proportions necessary for satisfactory yield, workability, and quality of concrete mixtures. The void determinations are usually made on the aggregate graded as it is to be used in the concrete mixture and in a stated condition of compactness. The voids in concrete aggregate are usually determined by a mathematical calculation from the specific gravity and unit weight. Increasing the proportion of fine aggregate results in smoother working mixes, greater surface areas to be coated, and more voids to be filled with cement paste. Sand produces a denser concrete than stone screenings of similar-sized grains.

The void content of concrete is influenced by the grading of the aggregate. When the proper ratio between the solid volume of coarse aggregate in a unit volume of concrete and the solid volume of coarse aggregate in a unit volume of dry-rodded coarse aggregate is used, practically all differences in coarse aggregates which will affect the proportions are allowed for automatically. Stone, generally, has a greater percentage of voids than gravel, but the above method of proportioning results in just enough extra mortar to fill the extra voids. If coarse aggregates are graded differently (thus creating different percentages of voids), this method allows for that; and, if aggregates have different specific gravities, that difference is also taken care of. The shape of the coarse-aggregate particle has an indirect effect on the strength of concrete, but that effect is entirely a reflection of the effect of void content on the requirements for mortar to produce a concrete of suitable workability.

Maximum Size of Aggregate

For a fixed maximum-particle size, one particular grading will give a greater weight per cubic foot than any other grading. Aside from the economy to be obtained from the use of large sizes of coarse aggregate, there is some advantage in the reduction of amount of cement paste required; and, often a larger size of coarse aggregate can be used, if the percentage of the maximum size is held down. The effect of the maximum size of aggregate on the efficiency of the cement can be measured also in terms of amount of water required with a fixed amount of cement to produce concrete of a given slump.

In Fig. 4, where a cement content of 5 sacks per cu. yd. of concrete and slump of 3 to 5 in. are maintained, the figure shows that the amount of water to give this slump decreases as the maximum size of aggregate increases.

The objection to undersize material in coarse aggregate is that it increases size range of the fraction and tends to both segregate and congregate in the concrete mixture, thus defeating to some extent the purpose of size separation. As the maximum size of coarse aggregate increases, the amount of cement required to produce a given quantity of concrete decreases. In the gradation of coarse aggregate, with a fixed water-cement ratio and fixed consistency, increasing the maximum size of graded coarse aggregate from ¾ in. to 1½ in. or from 1½ in. to 3 in. permits the fine aggregate to be reduced by about 5 percent.

Water-Cement Ratio of Paste

Unless the proper corrections are made for the moisture content of the aggregates, the proportion of aggregates to water-cement paste and the yield of concrete per unit quantity of cement will be disturbed. The variation will be considerable if the moisture content of the aggregates varies as much as 3 or 4 percent. Coarse aggregates will carry less surface water than fine aggregates, with the approximate quantity per cubic foot varying from ¼ gal. for coarse aggregates to 1 gal. for fine aggregates. Approximate

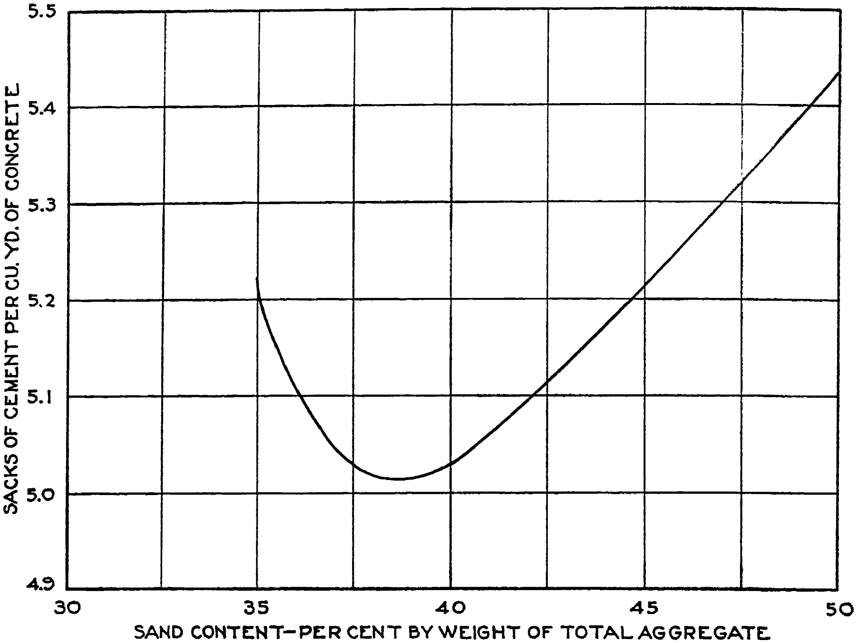

Fig. 3.—Effect of Sand Content on Paste Requirement.
Medium consistency; 6.37 gal. water per sack of cement; sand graded 0—No. 4 sieve; gravel graded No. 4—1½ in.

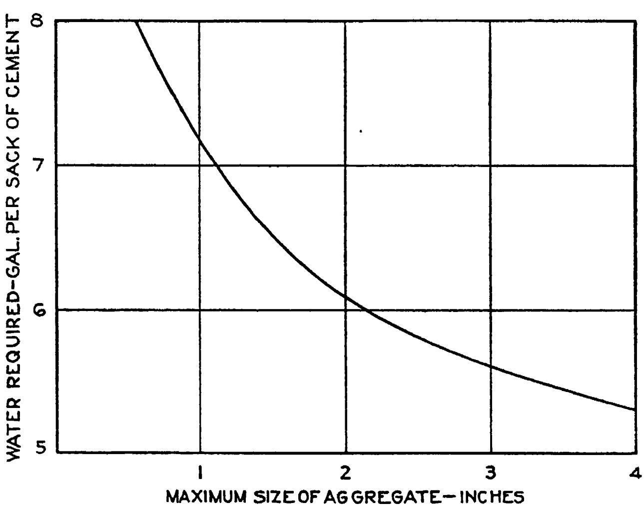

Fig. 4.—Effect of Maximum Size of Aggregate on Water Requirement for Concrete of 3 to 5-In. Slump with 5 Sacks of Cement per Cu. Yd. of Concrete.

Only by careful grading is it possible to use a low cement factor without sacrifice of workability. When the pieces of aggregate are separated by mortar, they have an opportunity for motion. Since sand has a great surface-area, the greater the quantity of sand above that required for workability, the greater will be the amount of water required for a given consistency—and, therefore, just enough sand should be used to accomplish the required workability.

Density of Concrete Mixtures

Density is affected more by a variation in the size of the fine-aggregate particles than by a variation in the size of coarse-aggregate particles. An excess of fine or medium sand decreases density. Density experiments indicate that an ideal curve of mechanical analysis having been found, raising the curve in any portion of its length decreases the density of the mixture. Mixes containing the greatest proportion of solid volume to total volume, consistent with desired workability, usually produce the best concrete. The densest concrete mixture is produced with well-graded coarse aggregate of the largest size, when the volume of sand, cement, and water is so small as to just fill the voids in the coarse aggregate. A fine aggregate, with grains all of the same size, produces mixtures having the least density. A mixture so graded as to give maximum density will be harsh, especially if particles are angular. By suitably increasing the proportions of medium and fine particles, sufficient workability can be gained without serious reduction in density.

Conclusion

It will be seen from the foregoing that aggregates have an important bearing on the design of concrete mixtures. Whether the method of design is empirical or theoretical, the characteristics of the aggregates being considered for use in the mixture must be carefully examined, if satisfactory concrete is to be attained. Such examination, regardless of the type of aggregate used, must include a study of the characteristics of the aggregate particles, taken individually and in any specific combination or size group.

The size, shape, surface characteristics, and specific gravity of the aggregate particles, and the grading, percentage of voids, fineness modulus, surface modulus and unit weight, of a combination of particles, will determine the amount of aggregate that can be used with a specified water-cement ratio, yield, and consistency, to produce the most economical concrete-mixture of the desired quality.

The aggregate is the most variable ingredient entering into the design of a concrete mixture. It has been shown that specifications which do not distinguish between rounded and angular aggregates may produce either an uneconomical mix with rounded aggregates, or an unworkable mix with angular aggregates. Aside from the quality of the aggregate-particle mass, particle shape has the greatest influence on the concrete mixture. The comparison between rounded and angular aggregates and information pertaining thereto in this report shows that, for the same slump and maximum size of aggregate, the use of angular coarse aggregate will require more fine aggregate and more water per cubic yard of concrete than when rounded aggregate is used. It is also pointed out that, with a constant cement content, a lower water-cement ratio may be used with rounded aggregate than with angular aggregate. The use of the proper amount of any type of aggregate in a mixture, with the grading controlled, will result in a saving in cement, which is the most expensive ingredient in concrete.

From the information presented in this report, it is apparent that aggregates have widely different characteristics which affect the proportioning of concrete mixtures; and, inasmuch as aggregates, from the same source, may vary from day to day in average diameter of particles, absorption, specific gravity, density, moisture content and bulking,

absorption of aggregates ranges from 1 percent by weight for sand, gravel, or crushed stone to a much higher percentage for very light and porous coarse aggregate.

The published information on the comparative use of rounded and angular coarse aggregate in concrete mixtures is rather meager. A review of this information shows that, when angular or rounded coarse aggregate is used, there exists a difference of opinion among investigators as to which ingredients in the concrete mixture should be held constant and which should be varied. One mix-design procedure is based on using a constant slump and maximum size and weight of coarse aggregate, and varying the amount of the fine aggregate with the water-cement ratio. Using a constant yield, the water-cement ratio is varied with uncrushed gravel or stone aggregate. The values in Table 2 show a maximum increase in water-cement ratio of 0.14 (or 1 gal. of water per sack of cement) when the shape of aggregate particles is changed from rounded to angular in a mix designed with the same yield. A second procedure is based on using a constant slump and maximum size of coarse aggregate, and varying the gallons of water per cubic yard of concrete and yield with rounded or angular aggregate. A third procedure for adjusting mix design for the use of rounded or angular aggregates is based on varying the weight of both aggregates per sack of cement, the sand as a percentage of the total aggregate, and the yield—with a specified size of coarse aggregate, water-cement ratio, and slump held constant.

Slump

The slump test is a very rough indication of workability, when the coarse aggregate consists of rough, angular particles and, therefore, cannot be used as an absolute basis for comparing the workability of mixes using aggregates having different particle shapes. Although the slump test is the most widely-used test for the workability of concrete mixtures, the results are rather erratic; and there is a need for some practical means to replace the slump-test method for determining workability on the job. There is also a need for the revision of concrete specifications to provide economy in cement by increasing the amount of coarse aggregate when a rounded aggregate is used, and to provide maximum amounts of each coarse aggregate for the same degree of workability. The slump test is of little value in determining the workability of dry mixes, because of the crumbling that sometimes takes place when the cone is removed.

Workability

The amount of coarse aggregate in a concrete mixture has a most important influence on its workability. The workability of concrete mixes using a given aggregate will remain approximately constant over a practical range of yield, if both the water and the coarse aggregate per unit volume of concrete are held constant. The relative properties of fine and coarse aggregates and the total amount of aggregate depend on the required consistency, water-cement ratio of concrete, and aggregate gradation. Aggregate gradation is a major factor in controlling the unit water requirement, percentage of sand, and cement content of concrete mixes for a given degree of workability. To maintain a given slump an increase in crushed aggregate requires an increase in the water content, although some loss in workability may be expected, particularly for lower percentages of sand. Owing to the unavoidable angularity of their particles, crushed-stone mixes require higher water and cement contents to avoid harshness and poor workability. Tests indicate that the use of properly prepared crushed-rock aggregate will result in fairly workable concrete mixes. Well shaped particles of aggregate, with minimum angularity and small difference between their greatest and least dimensions, are conducive to better workability.

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Report on Assignment 8

Specifications for the Construction and Maintenance of Masonry Structures

W. R. Wilson (chairman, subcommittee), C. C. Cooke, A. B. Fowler, R. E. Paulson, Louis Rossman, C. M. Segraves, C. A. Whipple, V. E. Williams.

Your committee feels that there is a definite need for a simplified explanation of basic principles of concrete mix design and control A large part of the concrete placed on the railroads consists of relatively small jobs (culverts, station platforms, etc.), much of which is placed under the supervision of a masonry foreman, a bridge and building supervisor, or, in some instances, a young engineer from the division office. Many of these railroad employees have learned by experience only and do not understand the fundamentals of proportioning, mixing, placing and curing necessary to obtain good, durable concrete. In many cases their desire to increase their knowledge of concrete work is subdued by the technical terms and expressions used in a text book or concrete manual. For the past two years your committee has been working on a guide, intended to explain the basic principles of concrete manufacture. This has required considerable study and review. The complete text has been rewritten several times in an effort to keep the explanation in simple, nontechnical terms, always with the thought of presenting information to stimulate the interest of the young inspector and masonry foreman toward a better understanding of this subject. After much concerted effort, collaboration and debate, your committee presents as information the following Guide to Water Cement Ratio Method of Making Concrete.

Guide to Water-Cement Ratio Method of Making Concrete

Introduction

AREA Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures are the backbone of railroad concrete work whether done by a contractor or by railroad forces. This guide is intended to explain the basic principles of concrete work, proportioning and the provisions of the specifications.

Summary

1. The most important thing is the amount of water used and its control.
2. Never increase the specified amount of water per sack of cement. Water added to the mix must take into account both excess surface moisture and water required for absorption in the aggregates.

constant inspection and periodic testing must follow the original sampling and examination of aggregates if satisfactory concrete is to result.

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17. A Method for Proportioning Concrete for Compressive Strength, Durability and Workability, by A. T. Goldbeck and J. E. Gray, National Crushed Stone Association Bulletin No. 11, December 1942.
18. Materials Required per Cubic Yard of Slag, Stone and Gravel Concrete and Cement Mortar, by Fred Hubbard, National Slag Association, 1940.
19. Proportioning Concrete Mixtures, by Stanton Walker, National Sand and Gravel Association Circular 21, October 1941.
20. Handbook for Concrete and Cement, War Department, Corps of Engineers, U. S. Army, October 1942.
21. ASTM Standards on Concrete and Concrete Aggregates, by Committee C–9, February 1947.
22. Concrete Information—Influence of Aggregate Characteristics on Proportioning Concrete, PCA No. ST 38, Second Edition.
23. The Application of Some of the Newer Concepts to the Design of Concrete Mixes, by W. M. Dunagan, Proceedings, ACI, Vol. 36 (1940).

Other important things about concrete are the following:

1. The longer the mixing time within reasonable limits the better the concrete. After 1½ or 2 min. with modern mixing machinery you do not gain enough to make it worth the extra cost of longer mixing. The 1½ or 2 min. called for in your specifications mean the length of time that must elapse after all the materials—and water is one of them—has gone into the mixer until any part of that batch is dumped.

2. Some aggregates are better than others but as between any two satisfactory kinds that will meet specification requirements the difference in concrete does not amount to much.

3. Any American portland cement accepted by the railway company will do more than you ask if you will only do your part in making concrete. Besides the normal portland cements, manufacturers now produce both quick hardening and slow hardening portland cements for specific uses. Quick hardening is used where time is important or cold weather protection is costly. Slow hardening cement is used in very massive structures where it is important to keep the internal heat generated at a minimum, thereby reducing contraction when cooling.

4. Curing plays a big part in strength and the longer the curing under the proper temperature and moisture conditions, the better the concrete. This is important in making good concrete, and should never be neglected.

5. The same conditions which produce strength make for density, toughness, watertightness and resistance to weathering and wear.

In addition to the above, there are definite methods to be followed to get exactly the kind of concrete that is desired. These will be explained in Chapter 2 on "Proportioning Concrete."

Water-Cement Ratio Strength Law

6. The water-cement ratio strength law is as follows:

> *For given materials and job conditions, the strength of concrete depends upon the amount of water per sack of cement (the less water the higher the strength) SO LONG AS THE CONCRETE IS PLASTIC AND WORKABLE.*

(a) Water: The scheduled amounts of water are conservative and your average concrete strength should be several hundred pounds higher than those shown. If test cylinders are made on your work and any of them fall below the scheduled strengths, something is wrong, probably with your mix.

The amount of water is not only that measured into the mixer, but is also that carried in the aggregates. The sum of the two is to be considered the amount of water per sack of cement.

(b) Water in aggregates: Every concrete man knows that after or during a rain he has to cut down on the amount of added water or else his concrete is too wet. In wet weather this is at its greatest, but there is usually some water present in the sand and often in the coarse aggregate. Fortunately it is a fairly simple matter to find out how much water there is, so that the proper corrections can be made in the water to be added at the mixer, as will be explained later.

3. It is permissible to decrease water-cement ratio if drier mix can be placed. However, this is not economical and a new mix should be designed with less cement.

4. Become familiar with decreasing or increasing aggregates to affect workability, holding water-cement ratio constant.

5. If other test cannot be made, the water should be drinkable.

6. Be on the alert for changes in aggregates and handle so as to avoid separation of the sizes.

7. It is necessary that the same amounts of aggregates be used in each batch. Weighing the materials in each batch is the most satisfactory method.

8. Proper handling of cement, especially protection from moisture, will save trouble.

9. Use the slump tests as a guide to consistency.

10. Do not "beat" the specified mixing time.

11. Take care in placing concrete. Avoid separation and remove laitance.

12. Temperatures below 42 deg. F. require special precautions. Use a thermometer and heat materials, if necessary.

13. Protect concrete from drying out and from low temperature during the curing period.

14. Reinforcement must be accurately placed, securely fastened, and protected to avoid displacement.

15. Good forms insure good-looking concrete.

16. Take full advantage of mixer capacity.

17. Take decent care of mixing equipment.

18. Poor concrete is expensive at any price.

19. Good concrete is a lasting monument to you.

Chapter 1.—Basic Principles

General

The secret of good concrete is this: Strength, durability and watertightness of concrete depend primarily on the amount of mixing water used for each sack of cement within workable limits.

You may ask what part the proportions of the other materials play in the matter and the answer, given in two parts, is:

(a) If the sand and coarse aggregates are of suitable quality and in even fairly good proportions to each other, the amount of aggregates per sack of cement has practically nothing to do with the strength. True, there is a limit to how far we may go, but it is much greater than you would think possible.

(b) Changing the amount of aggregates per sack of cement with a fixed amount of water affects the workability, so that the most you can use is that amount which gives the stiffest concrete you can handle on the particular part of the work under way. The more nearly you come to the best ratio of sand to coarse aggregate (gravel, slag or crushed rock), the more total aggregates (fine and coarse) you can use without making the mix too stiff or harsh for your purpose.

also see the importance of getting the proper mixture of cement and water to make the glue to fasten the mass together.

Water Per Sack of Cement

It has been found that the strength of the concrete, with all other conditions being equal, is dependent upon the amount of water per sack of cement used in mixing. The less water used, the stronger the concrete and likewise, the more water used the weaker the concrete. On most jobs the gallons of water per sack of cement will be specified either on the plans or in the specifications. This water includes that already present in the sand and coarse aggregate as well as the water added at the mixer.

TABLE 5.—APPROXIMATE QUANTITIES OF WATER CARRIED BY AVERAGE AGGREGATES*

Very wet sand	¾ to 1 gal. or	6¼ to 8⅓ lb. per cu. ft.
Moderately wet sand about	½ gal. or	4¼ lb. per cu. ft.
Moist sand	¼ gal. or	2 lb. per cu. ft
Moist gravel, crushed rock or slag	¼ gal. or	2 lb. per cu. ft.

* The coarser the aggregate, the less free water it will carry.

If the amount of mixing water is not given, Table 1 will give you the total amount per sack of cement for the structure concerned.

Sampling Aggregates

The most carefully designed mix means nothing unless you get a representative sample of the aggregates for use in making the trial mix.

In a job stock pile you are most apt to get a representative sample halfway up the pile and about a foot in from the surface. In a car it would be wise to take a point halfway between the center line and the side and midway between the middle and end, digging down a foot or so into the heart of the load. These are merely the points shown by past experience to be the best, but fixed rules should never take precedence over your judgment. Remember, there is a tendency for the larger pieces of aggregate to work to the surface of the pile or load and that gravel or crushed stone always gives the outward appearance of being coarser than it really is. Keeping this in mind, do not select any sample that does not look representative.

Trial Mix

The proper proportions for the concrete mix can best be determined by trial and in recent years this method has become standard practice. However, unless you are familiar with concrete mixes, proportioning by trial is rather laborious without some guide for the first trial mix. Table 4 is provided to give the first mix.

This table gives the amounts of sand and coarse aggregates (either gravel or crushed rock) of various sizes for a total water content of from 5 to 7½ gal. per sack of cement. It can be used for either weight or volume of aggregates. The amount of water to be added at the mixer is based on a moderately wet sand (4 percent moisture content). If the sand is very wet, the water added should be reduced. Table 5 will assist you in determining how much to reduce the water. The proportions are such as to give about a 3-in. slump. If a greater slump is desired reduce the sand by 10 lb. or 0.1 cu. ft.

Method of Measurement

7. Due to the many variables, with the attendant inaccuracies they introduce unless great care is exercised, measurements of the aggregates by volume have generally been abandoned. The much more accurate method of measurement by weight has become standard practice wherever possible. With this method, only small corrections to accommodate changes in moisture content of aggregates, are necessary as the bulking due to looseness and moisture can be disregarded.

Proportioning

8. General: Whether evident to you or not, it is quite true that the best proportions of sand to coarse aggregate, and of both to cement, depend upon the workability wanted and the traits of the two aggregates. The amount of the water and the slump are already fixed for you by the specifications and class of concrete to be made.

Although it has a slight bearing upon strength, this matter of best proportioning means producing the desired quality of concrete at least cost. (The cement accounts for about half the material cost.) What would be best for a well graded gravel and a medium sand would not work for a badly graded stone and a very coarse sand.

The ratio of the cement to the aggregates is governed to a great extent by the variation of the size of the coarse aggregate. The larger the aggregate, the less surface there is to be glued together by the water-cement paste. As an example, 2½ in. max. size coarse aggregate will require approximately one sack of cement less per cu. yd. than the 1-in. size. It is well to remember that the larger the aggregates, the less cement is required for the same strength, but it is probable construction features will be the controlling factor.

The Slump Test

9. The slump test is the best way to keep a check on consistency that is simple enough to use in the field and can be handled with cheap apparatus. In the hands of a man who will use it properly it is a very useful danger signal. This is explained in Chapter 2.

Chapter 2.—Proportioning Concrete

General

Proportioning concrete is the method of finding the proper amounts of all of the materials to be used to produce the kind of concrete desired.

The ideal concrete is a solid mass without any place in it not occupied by some of the materials going into its manufacture. The fine particles of cement should occupy the spaces between the finer pieces of sand and these in turn should fill in between the coarser sand. Likewise, all the spaces between the coarse aggregate should be filled with the sand and cement particles and the smaller sizes of coarse aggregate.

All the particles making up this mass should be completely coated with the cement paste which acts as a glue to fasten them into concrete.

It is easy to see the importance of having the sand and the coarse aggregates composed of particles of all different sizes so they will fit together. You can

the excess level with the top of cone. Lift the cone carefully so as not to jar the concrete more than necessary. As you lifted the cone the concrete settled down to a certain extent. To measure this settlement or slump place the cone alongside the concrete and, with the rod as a straightedge across the top of the cone measure down to the top of the concrete at the middle. This measurement is the slump.

Appendix A—Instructions to Field Men

Study and experiments, as previously explained, have been made to find the mix best suited to the needs of the work at hand. You have to take care of many details in the field., which require constant attention, particularly in mixing and placing. The effect of negligence and mistakes in hardened concrete is difficult to cover up or correct, and stands as a memorial to their maker. You will be proud of a job well done when the forms are removed from a properly and carefully placed structure.

The following instructions follow the order of the AREA Specifications for Concrete and Reinforced Concrete Railroad Bridges and Other Structures. The numbers in parentheses after each section below refer to the corresponding section of these specifications. The instructions are basic and will apply equally to the specifications in use on your railroad.

I. Materials

1. Cement

The following are the types of cement that are manufactured. Types I and II are the kinds you will usually be furnished except where high early strength is needed and then you will get Type III.

Type I.—For use in general concrete construction.

Type II.—For use in general concrete construction exposed to moderate sulfate action or where moderate heat of hydration is required.

Type III.—For use when high early strength is required.

Type IV.—For use when a low heat of hydration is required.

Type V.—For use when high sulfate resistance is required.

Do not use cement that has become hardened or partially set.

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2. Mixing Water

You have no way of making chemical or mortar tests of the mixing water, but the taste is a good indicator. A water unfit to drink is apt to be bad for making concrete. If doubtful, send a sample to the laboratory so that tests can be made using the water in question, to make a mortar which can have its strength compared with mortar made with water known to be satisfactory.

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per sack of cement and the coarse aggregate by 20 lb. or 0.2 cu. ft. per sack of cement for each 1 in. of increased slump. If less slump is required, increase the aggregates by the same amounts.

The quantities given in the table may be used for the trial mix if a mixer is used. If you make the trial mix by hand 1/10 of the table quantities can be used.

After mixing, a slump test should be made and if the slump varies from that required, the aggregates should be varied as described above and a second trial mix made.

If the mix is too harsh, the amount of coarse aggregate should be decreased, and sand increased, if too sandy, a reduction should be made in the sand and an increase made in the coarse aggregate. If the sand is wet, any change in the amount of sand will also necessitate a change in the amount of water added to keep the total water per sack of cement at the amount prescribed.

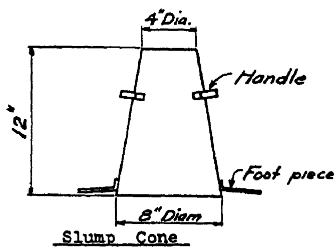
The Slump Test

If the amount of slump is not given either on the plans or in the specifications, Table 2 will give you the recommended maximum and minimum slumps for the structure concerned.

The materials required for this test are:

1 Slump Cone 4 in. top dia., 8 in. bottom dia., 12 in. high, handles and foot pieces on sides, made of No. 20 galvanized metal. (See sketch).

1 ⅝ in. or ¾ in. round steel rod, 16 to 24 in. long with one end tapered to a blunt bullet-shape point.



The Slump Cone.

To make the slump test, place the cone on a level flat nonabsorbent surface so it can be held securely with the feet. Fill it about ⅓ full of concrete. In placing each scoopfull of concrete the scoop shall be moved around the top edge of the mold as the concrete slides from it in order to insure uniform distribution of the concrete within the cone. Each layer shall be rodded with 25 strokes of the rod. The strokes shall be distributed in a uniform manner over the cross section of the cone and for each of the two upper layers shall penetrate into the underlying layer. Fill the cone 2/3 full and rod in the same manner. Fill the cone full and repeat the rodding process striking off

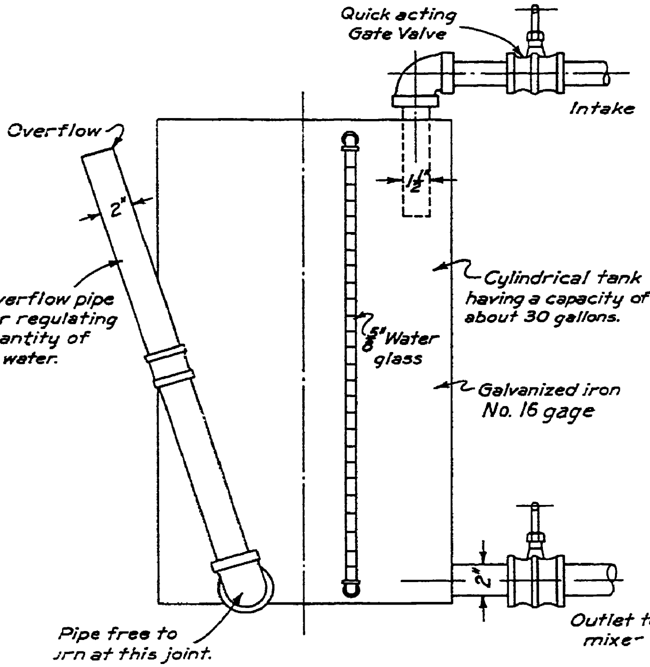


Fig. 1.—Device for Measuring Water.

3. Assumed Strength of Concrete Mixtures

The following table gives the minimum strength you should get after the concrete has cured for 28 days if Type I or II cement was used or after seven days if Type III cement was used. With care you should get concrete testing several hundred pounds per square inch above that specified.

Total Water Gal. per sack of Cement	*Assumed Minimum Compressive Strength at the Age of 28 days, psi.*
7½	2500
7	2750
6½	3000
6	3300
5½	3700
5	4250

The class of concrete specified on the plans has been determined by the type of structure, the location and the degree of exposure to the weather.

II. Workmanship

1. Measurement of Materials

The cement shall be measured in sacks or by weight from bulk. 94 lb. = 1 sack or ¼ barrel and is assumed to be 1 cu. ft.

Fine and coarse aggregate shall be weighed into the mixer, unless otherwise specifically authorized by the engineer.

Measurement by weight is discussed in paragraph 7, Chapter 1 and is the preferred method.

If volume measurement is authorized by the engineer, the wheelbarrows or measuring hoppers shall first be filled by weight and strike-off boards provided to maintain the proper volume thereafter. At frequent intervals a batch shall be weighed into the wheelbarrows or hoppers, in order to make necessary corrections caused by changes in grading or wetness that might occur.

The water can be either measured or weighed. Whatever device is used, it should be inspected and the valves checked for leaks. If the tank has an automatic shut-off valve, it should be calibrated for accuracy. *The point is that you must have some device that measures the same known amount of water into the mixer for each batch.* For small batches, a calibrated bucket can be used for measuring water. Nearly all the later type mixers have a satisfactory water measuring tank, calibrated both in pounds and gallons. See Fig. 1 for a type of measuring device which can be used.

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2. Water-Cement Ratio

The amount of water mixed with one sack of cement, determines the quality and expected strength of the concrete and is the basis of the mix you are using.

Water carried on the surface and between the particles of either the sand or the stone or both, combines with the cement as a part of the mixing water and must be deducted from the total amount specified in determining the amount of water to add to the mixer. On the other hand, if either the sand or stone or both, are unusually dry the water required to fill the pores of the aggregate must be added to that specified in determining the amount of water per sack of cement required at the mixer. The quantity of excess water carried by the aggregates can be determined by drying the sand and stone to a surface dry condition.

In the absence of definite surface moisture determinations, the approximate quantities can be used, bearing in mind that a cubic foot of aggregate weighs approximately 90 lb. See Table 5 Chapter 2 for the approximate quantity of surface water carried by aggregates.

Surface moisture in the aggregates can be determined in several ways other than by drying as above; viz., by inundation in a calibrated tube, by weighing under water or, if a stove is not available by mixing a small quantity of alcohol or gasoline with the aggregate and burning in an open pan. Any method sufficiently accurate and approved by the engineer can be used.

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6. Storage of Materials

Cement should not be delivered on the site too far ahead of the work. It will harden in time even under proper field storage, especially in a moist, humid climate.

The matter of observing recommendations on aggregate storage is hard to do on some jobs. Do the very best you can. Dirty aggregates are sure to produce poor concrete. When unloaded in tapering piles, the larger pieces of gravel or crushed stone always work to the outside and have a marked separation from the smaller pieces. The result is a change in the consistency of the concrete, depending upon what part of the pile supplies the batch.

If a clamshell bucket is used, segregation can be prevented by keeping the pile level and distributing the aggregate in layers beginning at the outside of the pile and working towards the center. The amount of aggregate stored in a given space can be increased by the use of flash boards at intervals in the slope of the pile. The point is to avoid separation of the various sizes. This is important to maintain the proper quality of the concrete. See Fig. 4 for methods of handling aggregates.

It is important that the reinforcing steel is stored off of the ground and prevented from rusting. If scale and loose rust get on the steel they will have to be removed, so it is much better to prevent their formation.

(209–210–211)

7. Forms

Remember that the appearance of the finished concrete depends on the alinement and finish of form surfaces in contact with the concrete. The forms shall be strong enough and so braced that they do not move under the weight of the fresh concrete before it sets.

In deciding on the strength of forms necessary to resist the pressure of concrete, it is more important to consider the expected rate of pouring than the height of the wall or pier. When the pour is slow, the concrete at the bottom will take some initial set before the form is filled, thus reducing the pressure at the bottom.

For a normal rate of pouring, satisfactory forms can be built as follows:

> *Walls Up To 10 Ft. In Height.*—1-in. tongue and groove sheeting—2 in. by 4 in. studs—16 in. centers. 4-in. by 4-in. or 2-in. by 6-in. walers, first walers to be placed not more than 12-in. from the bottom and spaced from there upward, starting at 24 in. and increasing to 36 in.
>
> *Walls Up to 24 Ft. In Height.*—1-in. sheeting—2-in. by 6-in. studs—12-in. to 14-in. centers. Double 2-in. by 6-in. walers, the first waler to be spaced not more than 12 in. from the bottom and spaced from there upward, starting at 30 in. and increasing to 45 in.

The forms should be securely tied together by twisted wire ties or bolts. Many patented ties which also act as spacers are on the market. When bolts are used, it is usually economical to use double walers with space enough between the two timbers to allow the bolt to pass through, thus avoiding boring the waler timbers.

When the job is large enough so that forms can be reused, it is sometimes more economical to make up panels of ¾-in. plywood.

4. Workability

Your concrete must be so made that it will work into place without excessive tamping and that it will not be so harsh as to give honeycombed surfaces. Neither must it be so mushy or sloppy as to cause separation of the mortar from the aggregate and a rise of water in the forms. The proportions for a workable concrete should have been determined by the designer of the mix. However, if for some reason, the mix being used is too stiff, the weights of sand and stone can be reduced slightly, keeping the water and cement the same. If the mix is too mushy it can be dried up by adding small amounts of sand and stone, *providing the wetness is not caused by wetter sand and stone* than used in the design in which case the amount of water added to the mixer should be reduced accordingly.

The slump test is a method of measuring the consistency and indicating the workability of concrete by means of the slump cone. Details of taking the slump are given in Chapter 2. It is not a measure of the water ratio in general, but serves only as an indicator of the quality of the concrete when used with the same sand and stone in the same mix and when it is known what slump to expect with the desired amount of water. It is a measuring stick to assist you in controlling the quality of the concrete you are making, as the eye alone is a poor judge. The limiting slumps given you are for your guidance, as well as for the designer's. Stiffer mixes than those shown increase the labor required in placing and tend to produce porous honeycombed concrete. Mixes wetter than those given will cause water gain, laitance, and weak concrete.

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5. Water Gain

Water gain, or bleeding, is the gradual increase in the water coming to the surface of the concrete as it is being poured. If excessive this usually indicates that more water is being used than necessary.

To correct excessive water gain, first reduce the amount of water added at the mixer. This will come nearer to keeping the ratio of cement to water constant, as the excess water will be taken up in the dryer mix. Adding more aggregates would stiffen the concrete, but would result in a higher ratio of water to cement, producing a poorer quality of concrete. After the excess water in the forms has been taken up, and if *the excess water in the mix was not due to wetter aggregates,* additional sand and stone can be added and the water setting brought back to normal. In other words, the mix was designed for more slump than was necessary for placing in the structure.

If the reduction of water as outlined above does not stop the water gain it might be caused by several things such as harsh aggregates, smooth nonabsorbent aggregates, poorly grading of aggregates, lack of fines in the sand or a poorly designed mix. A change can be made in the mix but if the bleeding still continues it will be necessary to get rid of the excess water. This excess water which has washed some of the cement and finer sand (called laitance) cut of the mix, if not removed will result in a poor structure.

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If the temperature is below 60 but above 42 deg. F. during curing the times given above should be doubled.

In any case forms shall not be removed from the concrete until it is sufficiently hard to permit of this being done with safety.

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9. Metal Reinforcing

The reinforcement system is to a concrete structure what bones are to a human body. The whole idea is that the steel reinforcing system shall be so placed and secured that if you were to saw through the hardened concrete afterwards, you would find every rod where the plan showed it. This calls for care in the spacing and tying of intersections securely.

The reinforcing must be cleaned of any foreign substance or any rust that is loose enough to be removed with a wire brush. Of course, the strength of a bar depends upon its size, and a bar pitted by rust or otherwise plainly off-size, is not as big as intended by the man who figured the design.

Excessive bending weakens the steel. Straightening and rebending shall not be done unless approved by the engineer.

The following table gives the required lap of reinforcing bars for different strengths of concrete:

Concrete Strength	*Number of Dia. of Lap*	
	Plain Bars	*Deformed Bars*
2000	63	50
2500	50	40
3000	42	33
3500	36	29
4000	31	25

To use the table, pick out the figure for the strength of concrete and the kind of bar you are using. Then multiply that figure by the diameter of the bar and you have the length of lap, in inches.

When you leave bars sticking out so that future construction may be tied to your work something must be done to keep them from rusting. There are many black paints on the market which make a good rust preventive and can be removed later with gasoline or other solvent. Greases are not permanent protection and linseed oil paints are too hard to remove.

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10. Joints

Make your joints where the plan calls for them if it is at all possible to do so. Where the plans shows the concrete shall be made in one cast (pour) make it so.

A construction joint is least noticeable when the concrete at the joint is struck off in line with a form board so the joint will appear as a board line on the concrete face.

Concrete shrinks in hardening and if the concrete in a wall or column does so while the concrete in the beam is supported by the forms or shores, a crack is bound to develop. This applies to lintels as well because the bucks hold them up.

In making a keyway use a chamfered board at least 4 in. thick unless conditions require otherwise. The chamfering makes it easier to remove. It is

Outside braces are usually necessary to hold the form in general line while the concrete is being placed, but such braces should not be depended on to take the place of the ties or bolts in resisting the pressure of concrete.

In building the forms, only enough nails should be used to hold the parts together while it is being built. Excess nailing does not increase the strength and makes the stripping of the forms more difficult with consequent damage to the lumber.

When a wall or pier is battered, the upward pressure of the fresh concrete will raise and displace the form unless it is securely anchored to the footing by wire ties. Eyebolts or bent rods should be placed in the footing when it is poured to act as anchors for these ties.

Before a pour is started, the form should be carefully inspected to make sure that the bottom is tight and secure and that any outside corners are firmly held by yokes or cleats.

Before pouring, the surface of form should be brushed with a non-staining form oil or thoroughly wet down with water.

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8. Removal of Forms

There is usually a question as to the time to be allowed before removal of the forms. For the purpose of curing, they should be left on as long as possible. As a guide to the safe time for the removal of forms, when Type I or II cement is used, the following is a good rule to follow. When Type III cement is used, these values can be reduced.

In weather of a temperature above 60 deg. F., the minimum time after pouring for the removal of forms shall be as follows:

Wall forms and sides of beams	2 days
Column forms and forms under slabs of span less than 4 ft.	4 days
Slabs of span between supported girders or shoring between 4 and 10 ft.	6 days

Supports or shoring shall be maintained under horizontal members at least a minimum time after pouring in accordance with the following tables:

Beams, girders and flat slabs in ordinary building construction	3 weeks
Spans over 30 ft.	at least 1 month

Under all floors upon which building materials are being placed during construction, the supports or posts shall be left at least two weeks longer than specified in the above schedules.

In weather of a temperature below 42 deg. F., the forms and supports shall be left in place a longer period as determined by the engineer, depending upon the weather encountered.

All possible precautions shall be taken to prevent new concrete from becoming frozen as permanent injury always results. If the concrete has frozen, the form shall not be removed until it has had sufficient time to thoroughly thaw and set in warm temperatures. When in doubt, a test may be made by placing a piece of concrete in warm water or upon a stove, after which, if the concrete is properly set, it shall not show any deterioration due to such treatment. A similar test may be made directly upon the structure by submitting it to the flame of a blow torch, which treatment will not produce any melting if the concrete is properly set.

12. Depositing Concrete in Air

By cleaning out your mixer, hopper, chutes, carts and wheelbarrows whenever you finish concreting, you have saved yourself worry about hardened concrete and foreign materials getting into your batch. Be sure the space to be occupied by concrete is clean and the forms are either wetted or oiled. Do not deposit concrete in water particularly if flowing, as the flow washes out the cement. Be sure the reinforcing steel is in correct position and double check it, as a blue print is sometimes misread.

The best of concrete if, mishandled and improperly placed, will produce a poor structure and be a lasting disgrace to its maker. Good runways are needed to prevent separation or loss of the ingredients as well as to prevent personal injuries. Keep runways cleaned of splatter. (With the right proportions and consistency, you should have little spilling). The less vibration, the less segregation there will be. Pneumatic tired buggies are advantageous for this reason and much easier to handle.

It is very poor practice to dump all your concrete in one place in the forms and let it run or try to force it along. You will have a rocky spot at the dumping place even though it may not show on the surface. Dump it as near to its final position as possible and keep it level at all times. Chutes and sectional pipes cause harmful separation of the concrete unless properly designed and used. See Fig. 5.

You can see how easy it is to prevent the separation of stone and mortar and to save much labor in tamping and spading thus insuring a much better concrete job.

The form surfaces and reinforcing steel above the level of the concrete should be kept as free as possible of splatterings. Splatterings on the forms give a rough shoddy appearance to the face of the concrete when the forms are removed and the dried splatterings on the bars make a poor bond. Devise some form of hopper or trough with a narrow opening that guides the concrete clear of the forms. See to it that the form surfaces and reinforcing bars are kept clean. It is best not to carry too heavy a lift, particularly in hot, dry weather, as the lower lift hardens too much to bond well with the upper lift if too much time elapses between courses A light lift allows you to maintain a plastic surface approximately horizontal.

Concrete with as little as a 2½-in. slump will flow in a chute if it can be kept moving. Mushy concrete may refuse to start flowing if allowed to lie in the chute between batches, which is a good reason for a discharge hopper at the mixer to regulate the flow. The angle of the chute should be such as to allow concrete of the required consistency to flow without clogging the chute and without separation of the stone from the mortar. A steep chute with sloppy concrete will cause serious separation: on the other hand, stiff concrete will not flow in a flat chute. With a little study and experiment, you should be able to work out the right arrangement. The slope of the chute should be within the limits of 1 to 2 for stiff concrete and 1 to 3 for mushy concrete.

Concrete for pumping should be carefully designed for correct proportions so as to give maximum workability with the specified water ratio. Pumping is used on larger jobs difficult to place by other methods.

(236 to 240 incl.)

usually best to use dowels. The concrete surfaces of the joint should be roughened with a rake or similar tool to insure a better bond with the succeeding lift. See Section 16 for bonding.

Joints in waterproof construction need very careful attention especially if the concrete is to be subjected to water pressure. You should be sure to watch the consistency of the concrete at the joint and make sure there is no bleeding. The instructions on bonding (Section 16) should be followed. The surface of the joint shall be protected from loss of moisture and from any mechanical injury.

Vertical joints are difficult to make watertight and should be avoided unless absolutely necessary and then shall be installed only as directed by the engineer.

(225 to 228 incl.)

11. Mixing

If your mixer is not equipped with a water measuring device, one as shown in Fig. 1 can be made. You should be careful that the water is measured accurately and that the mixing time is not less than that specified. The capacity is usually marked on the name plate of the mixers. The mixer should not be overloaded, neither is it economical to run it partially empty.

Ordinarily the mixer that splashes or oozes water steadily out at the back is either overloaded or is set badly.

The time of mixing is very important and that specified, usually 1½ min., except for very large mixers, must elapse after all the materials (water is one of them) have gone into the mixer until any part of that batch is dumped. Speeding up the mixer does not mix any faster and does not permit you to reduce the time. The speed should be 16 to 18 turns per min. for a medium sized mixer.

If necessary, to save time in discharging, a hopper should be used from which wheelbarrows or buggies can be filled or an even flow in a chute maintained. If you have a hopper at the discharge end of the chute the hopper at the top will not be necessary if the chute is large enough so that mixer dumping does not overload it. If the job cannot keep up with the mixer, a longer mixing time will make better concrete.

Unless the work is close to the proportioning plant transit-mixed concrete will usually be sufficiently mixed. However, it is well to check this if you are getting ready-mixed concrete.

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If hand mixing is necessary it should be done on a watertight platform and not over ⅓ cu. yd. mixed in one batch. You should break your mixing board gang into two groups. This is done to reduce the intervals between batches. See that each group mixes its product to a uniform color and consistency before it is released to the next handling.

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Retempering is the remixing of partly hardened concrete with or without added water, cement or aggregates. It is dangerous business. If you have to stop work for quite some time and have a part of a batch on hand when you resume, throw it away.

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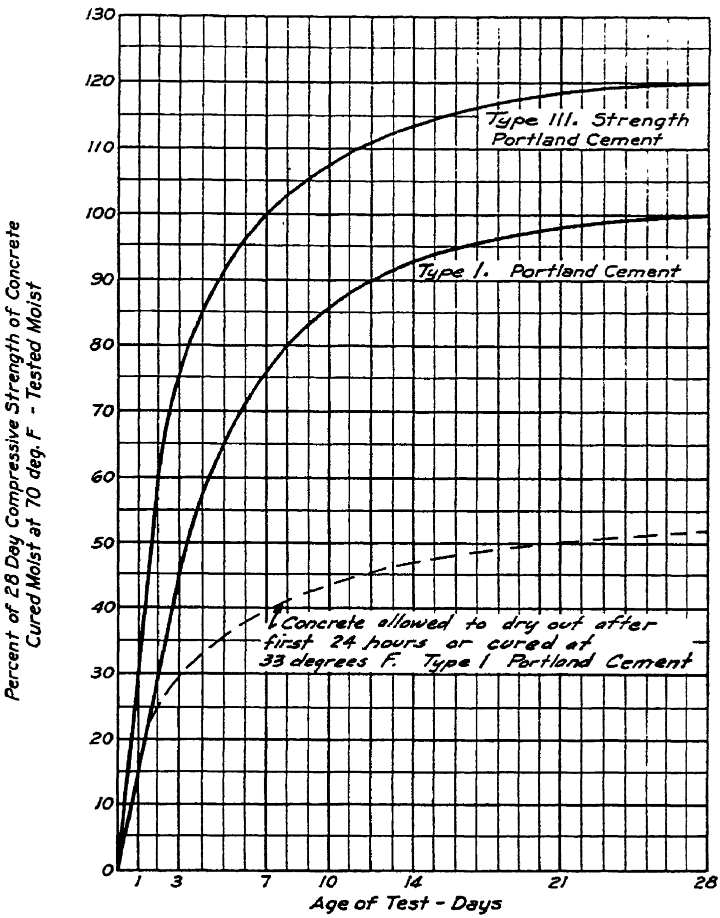

Fig. 2.—Curves Showing Percent Strength of Concrete, 1 Day to 28 Days.

15. Continuous Depositing

Plan your work so that when you once start placing the concrete you can complete the section of the work designed to be placed monolithic. If a shut-down of the plant becomes necessary, a construction joint should be made as described in Section 10.

16. Bonding

When it is necessary to deposit concrete on or against concrete which has hardened the forms should be tightened, the old concrete should be roughened, cleaned of all laitance and saturated with water. The longer in advance you wet down the forms and old concrete surface, the better. Vertical and horizontal surfaces, which are accessible should be scrubbed with a neat cement grout

13. Compacting

There are many tools for compacting concrete. Usually, the most useful one is a mortar hoe that has been straightened. Concrete needs help to get into place even if the workability is just right, but you can reduce the labor greatly by depositing the concrete as nearly as possible in its final position. A little vibrating of the forms and reinforcing rods is a good thing to do in any case, and at times it is the only way you can get the concrete into position. A hammer or maul struck on the waling and studs will get the result. Beating fast with light blows will not usually affect the line and plumb of the forms materially.

High frequency vibration is coming into general use and when properly employed is a very efficient means of compacting concrete in complicated forms as well as simple sections. Care must be exercised not to over-vibrate and cause separation of the stone and mortar with water gain and laitance. Stiffer mixes can be placed with vibration than by hand and it is recommended that concrete with more than a 3-in. slump should not be placed by vibration. Concrete to be vibrated should be slightly less workable than that to be placed by hand. In starting a job where vibrators are to be used, begin with concrete that can be placed by hand gradually stiffen the mix by adding more aggregate until the correct consistency is reached.

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14. Depositing Concrete in Cold Weather

In weather with temperature around 45 deg. F. or less, it is best to keep a thermometer on the work and find out just what the temperature is, as guessing is dangerous. Concrete hardens very slowly at low temperatures even if it does not freeze. Refer to Section 20 for details of curing concrete in cold weather, and Fig. 2 for the effect of improper curing on the strength.

We used to think cold weather concreting was risky, but there is no danger if we are careful to watch the temperature of the mixed concrete. In temperatures from 30 deg. to 45 deg. F., the concrete can be sufficiently heated, about 70 deg. F., by heating the mixing water. In temperatures much below freezing it will be necessary to heat both the water and the aggregates. There are many devices for heating the materials, depending on the size of the job and the equipment available. Water can be heated by a coil of pipe in a fire or in a small steam boiler connected as a water heater. The aggregates can be heated by steam pipes or by using a length of culvert pipe as a stove upon which the material is placed. You can devise some method which is satisfactory with the engineer. A flame heater in the mixer is suitable only for small increases in temperature. When a flame heater is used, additional mixing water will have to be used to take care of the evaporation, and for that matter, all heated aggregates will require more mixing water, as the evaporation in handling is greater than for cold aggregates. The slump is a good indicator of the amount of water being lost by evaporation. Salts or chemicals in amounts not injurious to the concrete do not lower the freezing temperature of the concrete sufficiently to be of much value and, besides, at those temperatures the concrete would be very slow in hardening. Therefore they should not be used, unless approved by the engineer.

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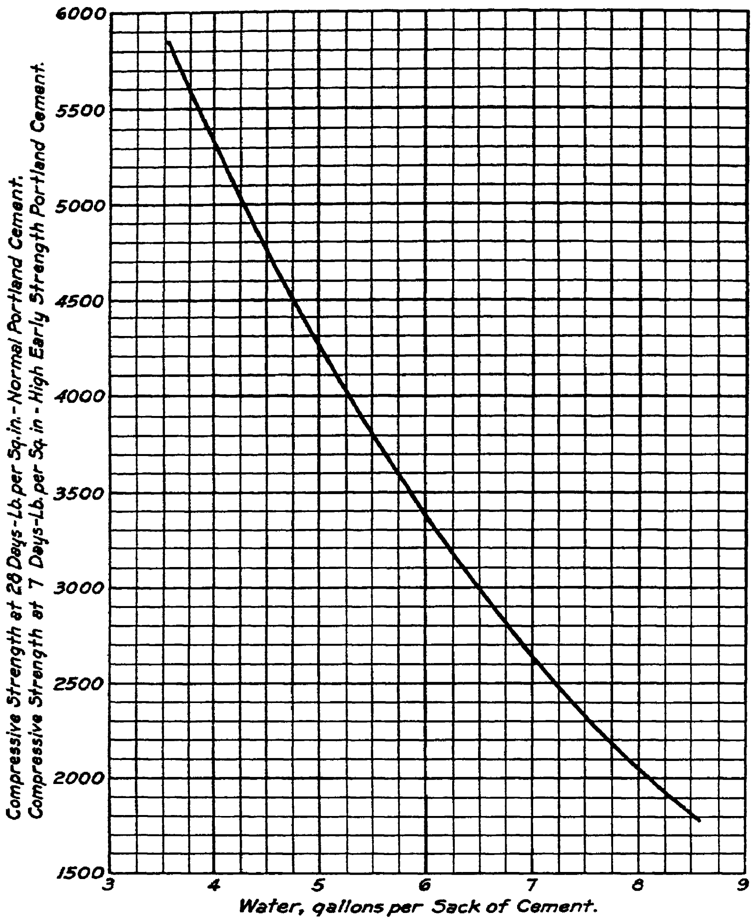

Fig. 3.—Water–Cement Ratio Curve.

of the same water ratio as the concrete to be placed. This grout should be placed just ahead of the new concrete so that it does not dry out or take its initial set. On horizontal surfaces where it is difficult to apply the neat cement grout, or wherever an excess of mortar is required, use a mortar the same mix as the concrete with the stone or gravel left out and the same amount of water. Let this flow ahead of the concrete being placed so as to insure a ¼-in. to ½-in. coating of mortar over the roughened concrete.

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17. Depositing Concrete Under Water

Concrete deposited under water can be of good quality if properly placed at temperatures sufficiently high to allow it to harden. Some experience is re-

quired to place it properly, so all operations should be approved by the chief engineer. The important thing is that concrete under water must be disturbed as little as possible. The reason is that agitation lets the surrounding water into the mass with an increase in the water cement ratio, resulting in a reduction in strength; also, the agitation causes some washing out of the cement. The water cement ratio at the time of hardening (setting) is the thing that counts. The laitance evil is only a natural result of too much water.

It is difficult to make a good construction joint under water. You can see why the work should not be interrupted until the seal is completed.

Not less than 6 sacks of cement per cubic yard should be used for placing under water.

The concrete should have a slump of not less than 6 in. nor more than 8 in. for concrete placed by tremies and not less than 3 in. nor more than 6 in. for that placed by bottom-dump buckets or in sacks.

The forms or cofferdams should be tight. The object is to place the concrete with as little disturbance as possible. Moving water will wash out the cement.

The less disturbance of the concrete in placing, the less laitance there will be to remove when the water is pumped from the cofferdam.

In using the tremie, the concrete must be of such consistency that it will flow into place unaided. There are three general methods of filling a tremie: (a) for a short tremie, place the lower end in a box partly filled with concrete, so as to seal the bottom, then lower into position; (b) plug the tremie with cloth sacks or other material, which will be forced down as the pipe is filled with concrete; (c) plug the end of the tremie with cloth sacks filled with concrete.

When using the drop bottom bucket, the concrete can be of stiffer consistency as it can be placed more nearly in its final position. The bucket shall be lowered very slowly until under water. Canvas flaps can be used as a cover to check backwash.

Bags of concrete should be placed carefully and can be used only in shallow water.

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18. Concrete in Sea Water

Concrete from 2 ft. below low water and 2 ft. above high water shall have not less than 7 sacks of cement per cu. yd. Other concrete in sea water shall have at least 6 sacks per cu. yd.

Concrete of 4000 lb. per sq. in., using 5¼ gal. of water per sack of cement, properly placed and cured, will be of high quality and durability.

Sea water should not be allowed to come in contact with the concrete until it has hardened for at least four days.

Make sure that all reinforcing is placed not less than 3 in. from any surface and at sharp corners not less than 4 in. No mental supports or ties shall extend to the surface of the concrete.

(260 to 262 incl.)

19. Concrete in Alkali Soils or Waters

Concrete placed in alkali soils and salt waters must be as impervious to water as possible to protect the steel from corrosion and to retard the forma-

1	¾	5	4250	4	185	235	2.0	2.4	3.65	7.4	180	190	1.9	2.1	3.38	8.0
2	1	5		4¼	170	270	1.8	2.7	3.75	7.2	170	220	1.8	2.4	3.46	7.8
3	1½	5		4¼	165	310	1.7	3.1	3.97	6.8	165	250	1.7	2.8	3.65	7.4
4	2	5		4¼	165	350	1.7	3.5	4.22	6.4	165	290	1.7	3.2	3.86	7.0
5	3	5		4¼	160	400	1.7	4.0	4.50	6.0	165	325	1.7	3.6	4.10	6.6
6	¾	5½	3700	4½	215	260	2.2	2.6	4.03	6.7	210	210	2.2	2.3	3.70	7.3
7	1	5½		4½	200	300	2.1	3.0	4.15	6.5	200	240	2.1	2.7	3.80	7.1
8	1½	5½		4½	185	340	2.0	3.4	4.36	6.2	190	280	2.0	3.1	4.03	6.7
9	2	5½		4½	185	390	2.0	3.9	4.66	5.8	190	315	2.0	3.5	4.22	6.4
10	3	5½		4½	185	435	2.0	4.4	5.00	5.4	190	360	2.0	4.0	4.50	6.0
11	¾	6	3300	5	240	280	2.5	2.8	4.36	6.2	240	230	2.5	2.5	4.03	6.7
12	1	6		5	225	320	2.3	3.2	4.50	6.0	225	260	2.3	2.9	4.15	6.5
13	1½	6		5	215	365	2.2	3.7	4.74	5.7	220	300	2.3	3.3	4.36	6.2
14	2	6		5	220	425	2.3	4.3	5.10	5.3	220	345	2.3	3.8	4.66	5.8
15	3	6		5	210	475	2.2	4.7	5.40	5.0	220	390	2.3	4.3	4.90	5.5
16	¾	6½	3000	5¼	270	305	2.8	3.1	4.74	5.7	270	245	2.8	2.7	4.36	6.2
17	1	6½		5½	250	350	2.6	3.5	4.91	5.5	255	280	2.6	3.1	4.50	6.0
18	1½	6½		5½	245	400	2.6	4.0	5.19	5.2	245	325	2.6	3.6	4.74	5.7
19	2	6½		5½	245	455	2.6	4.6	5.51	4.9	245	370	2.6	4.1	5.00	5.4
20	3	6½		5½	240	515	2.5	5.2	5.87	4.6	245	415	2.6	4.7	5.28	5.1
21	¾	7	2750	5½	300	325	3.1	3.3	5.10	5.3	300	265	3.1	2.9	4.74	5.7
22	1	7		5¼	280	370	3.0	3.7	5.30	5.1	280	300	2.9	3.3	4.82	5.6
23	1½	7		5¾	270	420	2.8	4.2	5.51	4.9	270	350	2.8	3.9	5.10	5.3
24	2	7		5¾	270	480	2.8	4.8	5.87	4.6	280	395	2.9	4.4	5.40	5.0
25	3	7		5¾	265	545	2.8	5.4	6.28	4.3	275	450	2.8	5.0	5.75	4.7
26	¾	7½	2500	6	335	350	3.5	3.5	5.51	4.9	330	280	3.4	3.1	5.10	5.3
27	1	7½		6	310	390	3.2	3.9	5.63	4.8	310	320	3.2	3.6	5.19	5.2
28	1½	7½		6	300	455	3.1	4.6	6.00	4.5	310	370	3.2	4.1	5.51	4.9
29	2	7½		6	300	510	3.1	5.1	6.28	4.3	300	415	3.1	4.6	5.75	4.7
30	3	7½		6	300	580	3.1	5.9	6.75	4.0	300	480	3.1	5.3	6.13	4.4

It is important that all concrete be protected from drying out or kept constantly wet for the period specified. Hardening of concrete is a chemical combination between the cement and water, so if the water is allowed to evaporate from the concrete, the hardening process is stopped. Proper curing is of such importance that job records should be required, as to the conditions of curing.

For protection from near freezing temperatures and to prevent drying of the concrete, various protective coverings are used.

(a) Surface remaining in contact with the forms: The forms are good protection against evaporation and against temperatures at or near freezing, and for this reason it is advisable to leave them in place as long as possible, wetting them down occasionally to prevent drying out.

(b) The surface of slabs protected by ponding. This method is no protection from low temperatures, but is ideal for wet curing of horizontal sections.

(c) Covering with burlap or cotton mats kept continuously wet: This form of protection is excellent for wet curing, but affords no protection from low temperatures.

(d) Covering with paper of suitable type: Paper covering will provide some protection from low temperatures and will retard evaporation from the concrete.

(e) Covering with layer of thoroughly wet sand: Earth or softwood sawdust. A 1-in. layer is sufficient for wet curing. For protection from cold a much thicker layer should be used.

(f) Covering with a 6-in. layer (loose) of thoroughly wet straw, hay, or similar material. This type of covering is good protection against temperatures at or above freezing and provides good wet curing.

(g) Continuous sprinkling of the exposed surface: This method provides good wet curing for vertical walls and surfaces where it is difficult to apply some form of covering. When possible, canvas or burlap hung over vertical surfaces helps to hold the moisture in place.

(h) Covering the surface with an approved curing compound immediately upon removal of the forms.

(266 to 268 incl.)

21. Test Cylinders

The number of test cylinders to be taken applies to all work, both company and contract. More test cylinders can be made if you so desire, or if requested by the engineer. It is desirable to make the test cylinders in pairs to provide for 7-day and 28-day tests.

The filling of the test cylinders should be done the same as for the slump cone, described in Chapter 21. The 6 by 12-in. cylinder is the standard size. For aggregate larger than 2½ in., the 8 by 16 molds should be used, but the 6 by 12-in. molds can be used if the aggregate larger than 2½ in. is screened from the fresh concrete before placing in the molds. It is important that you use a machined steel plate or plate glass as a base, and cover to insure plain and parallel surfaces. The samples of concrete from which the cylinders are made, can be taken from the concrete as it leaves the mixer, or after it is

tion of salt crystals within the concrete. Salt crystals (alkali is a salt) are similar to ice crystals in their expansive force in breaking up porous stone and concrete. Salt crystals grow by continued wetting and drying; therefore, the area of concrete subject to wetting and drying is the area most seriously affected. A horizontal seam or construction joint is a weak spot in the face of the concrete and the most likely place for deterioration due to salt and frost action to start. By keeping the joints well above ground and water, this source of trouble is eliminated.

Be sure all metal is well protected with at least 3 or 4 in. of good concrete, as specified, to prevent rusting with its resulting swelling action which will break off the surface of the concrete down to the depth of the steel reinforcing.

Your mix in alkali soils should have not less than seven sacks of cement per cubic yard.

(263 to 265 incl.)

20. Curing

Proper curing of concrete can make the difference between a poor job and one that you will be proud of. For the handling of concrete in cold weather refer back to Section 14.

Remember Type III cement hardens in approximately one-half of the time required for Type I or II cement.

To secure full strength, water-tight and durable concrete, it must be well cured with the proper moisture and temperature. When properly cured the gain in strength during the first week, is approximately as great as that during the succeeding three months. Once concrete has become thoroughly dry, there is no further gain, unless, at some later date, moist curing is resumed. For this reason, it is especially important to protect concrete from drying or chilling immediately after it is placed. For example, concrete which is kept wet for only one day and then allowed to dry, will be only about half as strong at 28 days as similar concrete which is kept wet the entire time. See Fig. 2.

The most favorable temperatures for curing concrete are from 70 to 80 deg. F. At higher temperatures hardening takes place more rapidly, but the concrete also loses its moisture much more rapidly unless special precautions are taken to prevent drying. As the temperate is lowered below 70 deg. F., the rate of hardening decreases until at 33 deg. (just above freezing), it takes more than three times as long to develop a given strength as it does at 70. No gain whatever can be expected while concrete is frozen. *Freezing within the first 24 hours is almost certain to result in permanent injury to the concrete.*

Unless it is being placed in extremely massive structures, concrete should not be placed when its temperature is less than 40 deg. F. When the temperatures are near or below freezing, the concrete should at least be between 60 or 70 deg. F.

Thermometers should be placed carefully to be in contact with the concrete surfaces, so that a true reading can be taken. Standard laboratory thermometers should be used as they can be placed in a small hole drilled through the form or protective covering or otherwise in direct contact with the concrete.

When necessary to provide heat, care must be taken to keep the concrete from drying out, as the heated air evaporates the water from the concrete quite rapidly.

The concrete is struck off carefully just after it is placed in the forms. This removes all humps and hollows leaving a true, even surface for the final troweling operation.

For sidewalks, driveways and some floors, an even yet gritty, non-slippery surface often is desired. When a finish of this type is required, final finishing is done with a wood float instead of a steel trowel. In some cases it is desirable to trowel the floor with a steel trowel before the final wood float finish.

Decorative finishes require care and good workmanship. They should not be attempted unless authorized and supervised by the engineer.

Definitions

The following definitions of certain terms reflect the sense as used in this guide rather than a strict accordance with scientific use.

ABSORPTION.—The soaking in of liquids by materials.

AGGREGATES.—A mass assemblage or collection of particles, usually sand and crushed stone, gravel or blast furnace slag, added to cement and water to make concrete.

ALKALI SOILS.—Soils with mineral salts present in quantity detrimental to concrete.

CALIBRATED.—The marking off to ascertain a set amount.

CHAMFERRED.—Removal of the sharp edges of a corner by rounding or beveling.

COMPACTING.—To pack the entire mass firmly together.

CONSISTENCY.—As applied to fresh concrete—a general term relating to the state of fluidity of the mixture.

CONTRACTION.—The act of shortening, narrowing or lessening the extent or dimensions, by causing the parts to approach nearer to each other.

CORROSION.—The wearing away or gradual decay of any substance through chemical attack. Rusting.

DURABILITY.—The power of lasting or continuing in any given state without deteriorating.

EVAPORATION.—The act or process of concentrating or drying by removing moisture.

HONEYCOMBED.—Concrete full of holes or cavities, usually caused by improper placement or compaction.

IMPERVIOUS.—That which permits no passage. such as that of water.

INGREDIENTS.—Something which enters into a compound.

INITIAL SET.—The time when first hardening begins.

INUNDATION.—To immerse in water.

LEACHING.—The removal of part of the material by the passage of water through the mass.

MONOLITHIC.—Materials formed into a single unit without any breaks or joints.

ORGANIC IMPURITIES.—The chemical compounds of carbon found in or with certain aggregates harmful to concrete.

PERIPHERAL.—The line bounding a rounded surface; more generally referred to in the specifications as the perimeter of a concrete mixer drum.

deposited in the forms. Cylinders should be left in the molds not longer than 24 hours. (Paper mold need not be removed). Before placing the cylinders to cure in water or damp sand, they should be plainly marked with a serial number and name of structure, or some identifying symbol, so as to be readily identified in the testing laboratory. They should be cured as nearly as possible at 70 deg. F. The usual test is 7 or 28 days. If possible, they should be forwarded so as to reach the laboratory several days before the desired test age is reached, so they can be placed in the curing room, properly capped and tested wet. The test cylinders should not be moved or shipped to the laboratory too soon after they have been made and between the time of making and shipping to the laboratory they should be carefully protected to insure good curing. The cylinders should be packed in wet sand, burlap or softwood shavings or sawdust, to prevent them drying out enroute to the laboratory. Hardwood shavings or sawdust, should not be used as they form tannic acid, which is injurious to concrete. Be sure that the cylinders are plainly marked with paint or yellow crayon (blue crayon fades); and that a letter of transmittal is mailed to the laboratory.

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22. Surface Finish

Good forms and good concrete well placed, should give a satisfactory surface finish. Patching, if necessary, should be done carefully, using a wooden float. A steel troweled surface is very noticeable. Do not use a brush coat; it gives an appearance of hiding something; usually, form board marks look better.

In finishing surfaces. such as the top of piers and abutments, keep the top surface slightly high so excess water and any laitance can be cleared off and the surface brought to grade with the wooden float after settlement has taken place. Remember to keep the surface wet for at least 7 days, (3 days if high early strength portland cement is used), to cure the concrete properly and prevent surface checks which allow deterioration to start with the entrance of water and frost.

Pavements and floors should be kept wet for not less than 10 days when Type I or II cement is used. Wet sand is good, as are also pools of water held by dams of clay or similar material. Never use sawdust if there is any chance of it being even partly from hardwood. Hardwood sawdust may contain tannic acid and that harms concrete. Instructions on curing have previously been given in Section 20.

Smooth finishes are produced with a steel trowel, care being taken to prevent too early troweling or excessive troweling. This care is required because troweling too soon or too much is likely to result in surfaces that will dust or which will develop numerous fine cracks called hair cracks. These can be avoided by proper finishing to produce surfaces that will be dense and smooth, and which will prove durable in service.

An important factor in producing satisfactory surfaces is the *time of finishing*. The best practice is to allow the concrete to stand until it is quite stiff, but is still workable. Then the steel trowel compacts the concrete and produces a dense surface. When the mixture is quite stiff, cement and fine material are not drawn to the surface under the action of the trowel. Consequently such finishes are free from objectionable dusting and hair checking.

Report of Committee 11—Records and Accounts

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To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Bibliography on subjects pertaining to records and accounts.
   Progress report, submitted as information .... page 414

3. Office and drafting practices.
   Progress report, submitted as information .... page 419

4. Use of statistics in railway engineering.
   No report.

5. Construction reports and property records: their relation to current problems.
   Progress report, submitted for adoption and publication in the Manual .... page 421

6. Valuation and depreciation:
   (a) Current developments in connection with regulatory bodies and courts.
   (b) ICC valuation orders and reports.
   (c) Development of depreciation data.
   Progress report on (a) and (c), submitted as information ....pages 423, 428

7. Revisions and interpretations of ICC accounting classifications.
   Progress report, submitted as information .... page 430

The Committee on Records and Accounts,
M. F. Mannion, *Chairman.*

AREA Bulletin 485, January 1950.

PLASTIC.—The property of fresh concrete that permits it to be readily molded, but which allows it to change form slowly upon removal of the confining mold. Plastic concrete maintains its homogenity while flowing sluggishly, neither crumbling through dryness nor segregating through overfluidity.

PRECEDENCE.—The act of going before; priority in time.

PROPORTIONING.—The measurement of the relationship between the component parts of concrete.

REPRESENTATIVE.—A sample which has the same characteristics and quality as those previously approved and accepted.

SEGREGATION.—As applied to fresh concrete, is the separation of fines and coarse aggregates in placing.

SILT.—Very fine material.

SLUMP TEST.—A standard method of test which measures the shortening in height of a standard test mass of freshly mixed concrete, used as a measure of consistency.

SURFACE MOISTURE.—The water in the aggregate in excess of that producing a saturated surface dry condition. Also referred to as free moisture or free water.

SYMMETRICAL.—Identically proportioned on either side of center line.

TYPES I–II–III CEMENT.—These designations are those established by the American Society for Testing Materials and govern their chemical requirements. Type I is for general use in concrete construction when the special properties specified for Types II and III are not required. Type II is for general use in concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required. Type III is used when high early strength is required.

WATER-CEMENT RATIO.—The ratio of the quantity of water to a unit quantity of cement. It is usually expressed in gallons of water per sack of cement.

WORKABILITY.—There is no standard or universally accepted measure of workability, but as used herein when applied to freshly mixed concrete, it indicates the ease with which it can be handled, transported and placed with a minimum loss of homogenity.

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Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

V. H. Doyle (chairman, subcommittee), M. M. Gerber. W. A. Krauska. G. B. McMillen. O. M. Miles, B. H. Moore, F. H. Neely, J. F. Piper, H. L. Restall, E. J. Rockefeller, J. E Scharper, H C Wertenberger, Louis Wolf.

This report is submitted as information.

The committee presents the following bibliography of subjects pertaining to railroad records and accounts for the period November 1948 to October 1949.

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Report on Assignment 3

Office and Drafting Practices

W. M. Ludolph (chairman, subcommittee), B. A. Bertenshaw, V. H. Doyle, Benjamin Elkind, J. P. Ferris, D. E. Field, A. T. Hopkins, W. A. Krauska, A H. Meyers, A. T. Powell, H. B. Sampson, R. L. Samuell, J. H. Schoonover, H. A. Shinkle, J. R. Traylor.

Your committee presents this report as information.

Considerable interest has been expressed as to what effect and what problems will arise in office and drafting practice due to recently enacted laws governing the registration of professional engineers in the various states.

A tabulated digest of the laws of the 48 states, Alaska and Hawaii is given on the adjoining page covering such points as might affect office procedure.

Such provisions of the laws as are of interest to the individual only, such as qualifications of the engineer, fees, methods of examination, etc., are not given.

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Report on Assignment 5

Construction Reports and Property Records; Their Relation to Current Problems

Louis Wolf (chairman, subcommittee), F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, W. C. Bolin, V. R. Copp, Benjamin Elkind, A. T. Hopkins, R. M. Nall, F. H. Neely, R. W. Scott, H. A. Shinkle, J. N. Smeaton, J. L. Willcox.

This report is submitted for adoption and publication in the Manual.

Construction reports and property records are very familiar to all railroad engineers and to most railroad executives. What becomes of these reports after they are made and how they affect, either favorably or adversely, transportation costs, and corporate earnings, are not so generally understood.

Effort is here made to point out some of the pertinent uses made of the reports as they culminate in the completion reports and in the valuation and property records of the carriers, and to stress the importance they have in various matters.

1. *Accounting for Cost of a Railway Acquired by Purchase, Merger, Reorganization, or Otherwise.*—In accounting for physical property acquired, the ICC accounting classification requires that "original cost or estimated original cost as found by the Bureau of Valuation" shall be recorded in Account 701—Road and Equipment Property. The classification also provides that past accrued depreciation on depreciable property be credited to the depreciation reserve accounts.

Probably one of the most significant of all uses made of construction reports and property records prepared by the carriers and reported on valuation returns to the ICC is embodied in the use here made of them in the determination of estimated original cost and in determining past accrued depreciation, in complying with ICC orders.

2. *Depreciation Accounting.*—This has been in effect since 1907 on equipment. The charge for depreciation on equipment is made monthly to operating expenses (Equipment-Depreciation).

Depreciation accounting became mandatory for 21 road accounts January 1, 1943 and 4 additional accounts came under depreciation January 1, 1945. Under the present rules for roadway depreciation accounting, depreciation bases are set up as approved by the Accounting Section of the ICC Bureau of Valuation for the 25 road accounts, using the original valuation and subsequent changes as reported in annual returns by the carriers. Rates are then developed by the carrier and approved by the Engineering Section of the ICC Bureau of Valuation. The resulting charge for depreciation is made monthly to operating expenses (Road Property–Depreciation).

3. *Federal Income and Excess Profits Taxes.*—Under certain conditions the Bureau of Internal Revenue recognizes and permits the use of depreciation accounting when applied for by the carrier. The bases and the rates that are acceptable to the Internal Revenue Department differ from those approved by the ICC necessitating the keeping of two sets of depreciation records and resulting in much extra work.

4. *Bankruptcy, Trusteeship, or Reorganization.*—The court requires the property records of the company and makes a request of the ICC for a report on its findings of the elements of value of property as prepared by the Bureau of Valuation. This report is not accepted as conclusive, but becomes an important factor in determining the financial structure of the reorganized company.

5. *Finance Cases, Stock or Bond Issues, or Refunding.*—The property records of the carrier are reviewed by the Bureau of Finance, or other body involved and are given consideration in their final approval of any financing authorized.

PARTIAL DIGEST OF STATE LAWS GOVERNING THE PRACTICE OF ENGINEERING AND LAND SURVEYING AS OF AUGUST 1, 1947.

STATE	Exemptions (Saving Clauses)						Registration by Endorsement (Reciprocity)			
	Employees of Privately Owned Public Utilities	Practice by Owner on His Property	Employees of Public Service or Interstate Corporations	Offering to Practice by Non-Residents	Non-Resident for Period of Months	Employees and Subordinates	Certification by National Council or Bureau of Engineering Registration Recognized in Law	Required That Other States Grant Reciprocal Registration to Registrants of This State	Required That Standards of Other States Be Not Lower Than Those of This Law	Required That Standards of Other States Meet Approval of This Board
Alabama			Y		2	Y	Y		Y	
Alaska		Y(d)			1(f)	Y(n)			Y	
Arizona					1(g)	Y(n)	Y			Y
Arkansas		Y			1(g)	Y		Y		
California		Y(e)		Y	2(g)	Y	Y		Y	
Colorado				Y	3	Y(n)				Y
Connecticut	Y				1	Y(n)	Y		Y	
Delaware				Y	1	Y	Y		Y	
Florida	Y(a)	Y	Y			Y	N	N	N	N
Georgia	N	Y	N		2	Y(n)	Y		Y	
Hawaii		Y			Y(h)					Y
Idaho					1(j)	Y		Y	Y	
Illinois (P.E.)					1	Y		Y	Y	
Illinois (S.E.)						Y			Y	
Indiana		Y		Y	1(g)	Y(n)	Y		Y	
Iowa					Y(k)	Y			Y	
Kansas		Y		Y	1	Y	Y			
Kentucky	Y		Y			Y(n)	Y		Y	
Louisiana								Y		Y
Maine			Y		1	Y(n)	Y		Y	
Maryland			Y		1	Y	Y	Y		Y
Massachusetts							Y		Y	
Michigan		Y	Y		2(m)	Y(n)	Y	Y	Y	
Minnesota	N		N	N	Y(f)		N	Y	Y	Y
Mississippi		Y			Y					Y
Missouri					1	Y		Y		
Montana				Y	1	Y	Y		Y	
Nebraska		Y			2	Y(n)	Y		Y	
Nevada					2(f)	Y(n)	Y		Y	
New Hampshire							Y			
New Jersey		Y	Y		1	Y(n)	Y			
New Mexico		Y			2	Y(n)	Y		Y	
New York			Y	Y	1	Y(n)	Y		Y	
North Carolina		Y		Y	1	Y(n)		Y	Y	
North Dakota					1	Y	Y	Y	Y	
Ohio	Y(b)	Y	Y(b)		2	Y(n)	Y		Y	
Oklahoma			Y	Y		Y(n)		Y		Y
Oregon		Y(d)		Y	1(g)	Y		Y	Y	
Pennsylvania	Y(c)	Y(e)			1	Y	Y	Y	Y	
Rhode Island					1	Y(n)	Y		Y	
South Carolina			Y		Y(f)	Y			Y	
South Dakota			Y			Y	Y	Y		Y
Tennessee			Y	Y	0.5	Y(n)	Y	N	Y	Y
Texas					2	Y(n)	Y		Y	
Utah		Y			2	Y(n)	Y			
Vermont		Y(c)	Y(c)		1	Y(n)	Y		Y	
Virginia		Y	Y		0.5	Y(n)		Y		Y
Washington					1	Y			Y	
West Virginia					2	Y(n)	Y	Y	Y	
Wisconsin			Y		Y	Y(n)	Y	Y	Y	
Wyoming		Y			Y	Y			Y	Y

Y-yes N-no
(a) If duly registered in another state and has 15 years practice.
(b) Applies to officers only.
(c) Provided one Professional Engineer is employed.
(d) Public Utilities not included in this exemption.
(e) Unless such practice involves the public health or safety or health and safety of employees.
(f) Provided that such person shall file application for registration as a Professional Engineer.
(g) Must notify the Board.
(h) May issue temporary permits.
(j) Provided the non-resident furnish the board certain information.
(k) Full time employees of any corporation while doing work for that corporation.
(l) If duly registered in another state.
(m) Provided State or Country grants equivalent privileges.
(n) Provided employment does not involve direct responsibility for design, inspection or supervision.

9. For consideration in connection with determination of proper switching charges.

10. Valuation data are being used in ex parte rate decisions. Also, in other rate cases and in cases involving the division of rates, wherein the relationship of the values of the properties involved is very important.

11. For preparing estimates to be used as a basis on which to secure the approval of new construction projects from time to time by the railroad managements.

12. For supplying ledger values provided for under the accounting classification of the ICC to be used in the abandonment of properties, sale of properties, and retirements which are made in connection with other property changes.

13. For determining the proper accounting as betwen cost of property acquired and operating expense changes in connection with property changes.

14. For protecting the company interests in meeting the demands of public authorities for the elimiation of grade crossings.

15. For arriving at proper insurance schedules covering properties that are insured from year to year, and the determination of fire losses that occur.

16. For preparing data to be used in complying with requirements of state commissions.

17. For protecting the company interests in connection with tax assessments made by the various taxing bodies, the preparation of income tax returns, and for ad valorem tax purposes.

18. For supplying valuation data for states, counties, cities, financial institutions, other corporations, and the general public, and for use in cost finding studies.

19. For development of the base, annual depreciation, and the depreciation reserve to conform with the requirements of the Bureau of Internal Revenue under depreciation accounting rules.

20. For facilitating the carrier's reviews of taxable income determined by the agents of the Bureau of Internal Revenue.

21. The valuation records are the most complete records available to the railroad management which indicate currently the details of quantities and costs of properties owned by or used by the various companies, and divided between the different kinds of property such as equipment, structures, tracks, lands, etc.

Report on Assignment 6 (a)

Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), P. D. Coons, Spencer Danby, M. M. Gerber, H. N. Halper, C. Jacoby, E. M. Killough, C. A. Knowles, G. B. McMillen, J. B. Mitchell, B. H. Moore, H. L. Restall, J. H. Roach, E. J. Rockefeller.

Regulatory Bodies

The Interstate Commerce Commission allocation of its appropriation for the Bureau of Valuation for the year beginning July 1, 1949, was considerably reduced from the amount allotted for the previous year. This reduction resulted from House action of curtailing $250,000 from the Commission's appropriation. This was based on the assumption that the Bureau of Valuation would be relieved of the requirement for reporting current reproduction cost and land values in its valuation work. The House did, however,

6. *Taxation: State or Local.*—Many state tax commissioners now inform themselves on the property changes reported to and valuations reported by the ICC, and these values are considered by state tax commissioners in fixing the taxable value of railroad property. Carriers should be alert to eliminate from the tax base public improvements. crossing protection or elimination, track elevation, bridges over navigable streams, and similar items constructed for public convenience or necessity rather than for transportation purposes.

7. *Rate Cases.*—Property records are used in rate cases both federal and state. Such cases often require lengthy and important exhibits.

8. *Contractual Relations Between Railroads.*—It is common practice to make use of the property records for agreements between railroads in determining the charge to be made for the use by one road of facilities of another.

9. *Retirements of Railroad Property.*—The construction reports and records required under the Valuation Act are used in making retirements from the accounts. Where actual costs are not known amounts given in the basic valuation are generally used.

10. *Cost Data as a Basis for Estimating.*—The detailed records kept as required for valuation afford a basis for estimating the cost of new work. The railroad construction indices and construction guide prices compiled from valuation data and issued annually by the Engineering Section of the ICC Bureau of Valuation are also useful.

11. *Fire Insurance.*—The property records maintained by the carrier are used in determining the amount of insurance to be carried and in establishing losses that occur.

12. *Maps, Profiles and Plans.*—One of the valuation requirements provided that each carrier maintain up to date maps that show the nature, extent, and location of its property. Prior to ICC valuation many railroads did not have the complete maps, profiles, and plans which are now found to be invaluable for the interpretation of other records, for the general purposes of railroad operation, and as preliminary data in connection with construction programs.

Expanding the foregoing and to emphasize its importance, the following are some of the special uses of the records.

1. For working up data to be used in formuating plans of reorganization, mergers, consolidations, etc., and as an aid in passing upon proposed reorganization plans, particularly as to the amount and classes of the securities proposed to be issued.
2. Valuation data by mortgage divisions, generally based on allocations by the Engineering Section of the ICC Bureau of Valuation, are used in the consideration of proposed mergers, consolidations, reorganizations, and refinancing.
3. For compilation of original cost to be used by railroads in setting up new investment accounts after reorganizations, consolidations, mergers, etc.
4. For compilation of rates of depreciation and original cost to be used by railroads in accounting for depreciation in accordance with the ICC requirements.
5. For preparing data to be used in making and passing upon applications for loans or financing.
6. For acquisition of properties from other railroads, individuals, and corporations other than common carriers.
7. To aid in fixing and checking the reasonableness of the compensation to be paid by or to the carriers for the use of joint facilities, important terminal stations, terminal companies, leased property, etc.
8. For making estimates as to the cost of trackage rights.

Rebuttal testimony and exhibits introduced by Witness H. T. Bradley, valuation engineer, Missouri Pacific Lines, were largely directed at the precedent established in Ex Parte 166, wherein the commission's finding of aggregate value gave no weight to the Bureau of Valuation's estimate of cost of reproduction, but instead used a formula based on estimated original cost plus the present value of land and working capital less the carriers' book depreciation reserve. The failure of the commission to give weight to present price levels in determining its aggregate value for a rate base was vigorously protested by the witness and in the carriers' brief, which was filed May 2, 1949. Notwithstanding the carriers' presentation, the commission, in its final report of August 2, 1949, had the following to say on the rate base value:

> *Valuation data.*—This is primarily a revenue case. In previous reports in this series of petitions for rate increase authorizations we have considered the question of the aggregate value for rate-making purposes of the property of the Class I railway carriers devoted to common-carrier service. The latest discussion is found in *Increased Freight Rates, 1947,* 269 ICC 33, pp. 48–49. We have brought these figures to the latest possible date, upon the best basis available from the record.
>
> According to this record, the value of the property in the common carrier service of the Class I railways is estimated at $20,978,646,326 as of January 1, 1948. This is based upon the original cost, except land and rights, plus the present value of land and rights, and an estimated normal amount of working capital, including materials and supplies, less the recorded accrued depreciation. The detail of these figures for the country as a whole and for the districts and regions is shown in the subjoined table.
>
> In 1948 the gross capital expenditures of the railways were very large, aggregating $1,266,000,000 in round figures. Valuation data showing the additional net investment during 1948 are not available. However, in view of the high prices of labor and materials, it seems safe to assume that the values on January 1, 1949, were appreciably higher than those on January 1, 1948, which are shown in the table.

Pipe Line Valuations

As previously described, the commission's method of arriving at the single sum value for all railroads has been set forth in its decision in Ex Parte 168, in which it is stated that this was a revenue case, and leaving the inference that it was not a valuation proceeding. In the case of the railroads, the commission took the estimated original cost and added land values and working capital. From this sum were deducted the depreciation and amortization reserves, leaving the figure found as the rate base value.

In contrast to the method followed in Ex Parte 168 is the method now being followed in valuing pipe line property. On October 26 the ICC served a tentative valuation report under Section 19 (a) on the Ajax Pipe Line Company. In this case the commission found a final value of $12,300,000 as of December 31, 1947.

The carriers' investment in road and equipment was stated to be $14,314,806; the reserve for accrued depreciation $8,579,254; the amortization reserve $355,898, or a total of $8,935,152. The carriers' material and supplies balance was $401,423 and cash on hand, $533,418.

The elements of value reported were: Cost of reproduction new, $20,237,119; cost of reproduction, less depreciation, $12,117,026; lands and right-of-way were given a present value of $210,631; the original cost of their lands and right-of-way was stated to be $334,053. Original cost to date for property other than land was found to be $13,943,419. Working capital was found to be $879,600.

recommend that $35,000 additional be granted for pipe line valuations. In the Senate, the amount for pipe lines was increased to $100,000, but the cut of $250,000 was not restored. The final disposition of the matter by the ICC left the Bureau with an appropriation that was reduced by $119,000. This necessitated the dismissal of 26 employees. Prior to this action, the Bureau had approximately 116 employees; the cut reduced the number to 90, of whom 70 were left in Washington, and 20 in the field, divided between 12 assigned to accounting and 8 to land. Twelve employees were dismissed in the central office and 14 in the field. This also necessitated the closing of accounting field offices in Washington and St. Paul, and the closing of land field offices in Boston, Cleveland, Philadelphia, Seattle and St. Louis. All together, seven field accountants and seven land appraisers were dismissed. Director Douglass advises, however, that all of the sections (Engineering, Land and Accounting) of the Bureau will continue to function as heretofore, and he requests that the carriers cooperate in showing patience and forebearance in requests made upon the Bureau. As directed by Congress, valuations of the pipe line properties will receive preference during this year.

During the year 1948 Class I carriers charged Account 459 Valuation Expenses an amount of $780,902, contrasted with $736,269 for the year 1947. As of October 1, 1949, all Class I carriers (136) had filed 588 returns through the year 1944; 134 through the year 1945; 126 through the year 1946; 114 through the year 1947; and 11 through December 31, 1948. The Accounting Section of the Bureau is now 92 percent in its field check of these returns.

The Engineering Section of the Bureau, having completed revised inventories for practically all carriers through the year 1932, is engaged in bringing their inventories forward to later dates and, as of October 1, 1949, was approximately 70 percent* current (long-form method). The work of the Accounting Section in bringing summaries of original cost other than land is 95 percent* current; the original cost of land is 39 percent* current. The Land Section in its work of revising land valuations to current dates has completed 77 percent* of its work. From the above figures, it will be noted that the Bureau is just about able to maintain a status quo in its progress and each year sees very little improvement in catching up with the backlog of work. With the further reduction in forces, above previously mentioned, it will be impossible for the Bureau to keep abreast of its work load unless Congress grants an increased appropriation to sustain the Bureau's activities properly.

Elements of Value as of January 1, 1949

Prior to the reduction in forces, previously mentioned and which became effective September 1, the Bureau of Valuation completed its estimate for each Class I carrier of the standard elements of value as of January 1, 1949. These will be furnished the individual carriers on request of the Director of the Bureau.

Ex Parte 168—Increased Freight Rates, 1948

Exhibit 1 in this proceeding was a statement prepared by the Bureau of Valuation showing for the United States, for each region, and for each Class I carrier its standard elements of value, consisting of cost of reproduction new, cost of reproduction less depreciation, original cost, present value of lands, and estimates for working capital; all prepared as of January 1, 1948, and following the methods used by the Bureau in other ex parte cases, such as 162 and 166. A statement of the Bureau's methods accompanied the exhibit. The findings in this exhibit were mentioned in last year's report of the committee.

* Based on 8,000,000 mile-years from basic valuation dates through 1948.

of the date of the previously found values that short-cut methods of approximating current value levels were considered unreliable.

The commission seeing the increasing need for bringing the values forward served valuation Order No. 28 on all pipe-line companies reporting to it as of December 31, 1947.

* * *

Prices.— . . . Period unit prices as of December 31, 1947, have been applied. The attempt is not to determine the exact price of a particular article on that date, for that price may have been abnormally high or low, but rather to ascertain what may be termed a normal price. The prices are based on investigation of prices over a period of many years giving appropriate consideration to the usual transitory nature of inflated prices occurring because of labor, material and food shortages during the war or post-war period. The price level used as of December 31, 1947, in accordance with past practice, is a long-term forecast and contemplates "tunnelling through" the war and post-war price peaks.

* * *

Engineering.—Engineering has been depreciated. It is a labor charge and ordinarily labor depreciates along with the article into the cost of which it enters.

* * *

Cost of Obtaining Money.—Six percent is the legal rate of interest in a large section of this country where no other rate is specified and our engineers and the working committee have come to an agreement as to the use of 6 percent as a guide.

* * *

Interest During Construction.—We have applied 6 percent and this rate is taken as including all other costs in connection with procuring necessary funds for construction.

* * *

Carrier lands.—The valuation act requires the commission to state the original cost and the present value of all carrier lands.

Present value as reported is nearly synonymous with market value. What is done is to ascertain the area of carrier land, to determine the market value of similar land adjoining or in the immediate vicinity per acre or other unit and to apply that price to the area.

* * *

Original cost to date.—The act requires the commission to ascertain and report the original cost to date of the property owned or used by every common carrier subject to the act.

For reasons stated in Appendix 3 to our report in *Texas Midland Railroad,* 75 ICC 1, we were generally unable at the time of the basic valuations to ascertain the original cost of railroad properties. Owing to the more recent construction of carriers by pipe line and our requirements for the recording of expenditures made by them the investment in and original cost of the properties of common-carrier pipe-line companies can be and has been ascertained. * * * While some items of property, the cost of which is included in our statements of investment and original cost, do not depreciate others wear out in service or become obsolete. Thus the original cost as determined represents, in part, property a portion of the service life of which has expired.

Contrasting the ICC methods followed in Ex Parte 168 with the method followed in the pipe line case, shows the following:

	A *ICC Method* *Ex Parte 168*	B *ICC Method* *Ex Parte 168* *Applied to Ajax* *Pipe Line Co.*
Original cost, except land	$24,565,000,000	$ 13,943,419
Present value of land	1,931,000,000	210,631
Working capital	703,000,000	879,600
	$27,199,000,000	$ 15,033,650
Less depreciation reserve	6,220,000,000	8,935,152
Estimated final value	$20,979,000,000	$ 6,098,498
Final value reported	$20,979,000,000	$ 12,300,000

	C *Assumed ICC* *Method in Ajax* *Pipe Line Case*	D *Estimated Value* *of Class I* *Railroads on* *Pipe Line Basis*
(1) Cost of reproduction new	$ 20,237,119	$36,391,000,000
(2) Cost of reproduction less depreciation	12,117,026	23,108,000,000
Percent of cost new	59.88	63.499
(3) Original cost	13,943,419	24,565,000,000
(4) Original cost less depreciation	8,907,056	16,581,000,000
Percent of original cost	63.88	67.499
(5) Weighted* average of (2) and (4)	10,756,962	20,381,000,000
(6) Original cost of land and rights	334,053	
(7) Present value of land and rights	210,631	1,931,000,000
(8) Weighted* average of (6) and (7)	286,326	
(9) Going value 3½ percent of (5)	376,494	713,000,000
(10) Working capital	879,600	703,000,000
(11) Estimated final value— Total of (5), (8), (9) and (10)	12,299,382	23,728,000,000
(12) Final value reported	$ 12,300,000	$20,979,000,000

* By multiplying each item by the percentage it bears to their sum and adding the products.

The tentative valuation just served on the pipe line company contains a statement of methods used and the following noteworthy excerpts are quoted from the report:

Foreword

Following the finding of final values for common-carrier pipe-line companies reporting to the ICC as of December 31, 1934, in accordance with Appendix 4, Statement of Methods, Valuation Docket 1203, Atlantic Pipe Line Company, 47 Val. Rep. 541, 584, Supplement No. 8 to Valuation Order No. 3, Second Revised Issue, was served on the reporting carriers.

The purpose of this order as explained on page 562 of the Atlantic Pipe Line Company decision was to keep the commission informed on all new construction, extensions, retirements, or other changes in the condition, quantity, use, and classification of the property. The same order was served on all pipe-line companies valued subsequent to December 31, 1934.

It became apparent as time went on that the previously found final values were far out of date. By the end of 1947 property changes had assumed vast proportions and price levels had changed so materially from those prevailing as

Transport Commissioners of Canada in a majority decision written by Justice M. B. Archibald, chief commissioner, condemned this use method and, as information, that portion of the decision is quoted below:

> The Canadian Pacific Railway urged strenuously that the overstatement of depreciation in rolling stock and the overestimate of depreciation of road property amounting in all to the sum of $4,000,000, as found by the board in the decision in the 21 percent case, was an improper finding and should not have been deducted in calculating that railway's requirements. Much evidence was given and there was much argument as to the whole question of depreciation and as to the respective merits of the straight-line method and the user method. The examination and cross-examination of the many witnesses called by the applicants on this point justifies a finding by this board that the straight-line method should have been adopted.
>
> Counsel for the Canadian Pacific Railway contended vigorously that the case for the user method of depreciation has been wholly and completely substantiated. I find, however, that I cannot agree with him. To the railway the user method may have certain aspects which recommend its adoption; of these I am not unaware. However, it is my view that it is the duty of the board to make a proper determination, having regard to the railway on the one hand and the users of the service on the other. This board is being asked to set, at this time, a general level of freight rates based substantially on the actual revenues and expenditures for the years 1947 and 1948. Depreciation is a substantial item of expense. The amounts of depreciation vary by the year and must necessarily do so so long as there be changes from one year to another in the degree of use to which the equipment and property is subjected, measured in terms of locomotive-miles, passenger car-miles and freight car-miles for equipment, and gross ton-miles for depreciable road property. In a period of intensive use the charge to depreciation by the user method is increased over what it would be, given the same rate applied to an equal service value if the intensity of use were less; the practical result being that depreciation expenses tends to rise and fall in accordance with the intensity of use and is reflected by a rise or fall in total operating expenses. Today total operating expenses are at a high level and one of the items accounting, in part, for this level is the depreciation charge. That the railway property is under a high degree of use today is evident from data placed before the board by the railway itself. If the board accepts the railway's contention respecting depreciation, it is, in fact, projecting into the future a fixed expense, which, in respect to the intensity of use of the equipment and property in the future, may well be inflated, and thereby setting a general level of freight rates, applicable to the future, which may be higher than warranted.
>
> For the reason above stated, it is my opinion that the board must determine what, in the best interests of all concerned, is a fair and proper depreciation charge to be included in operating expenses for rate-making purposes. The board is not bound to accept the submissions of either the railway or the respondents. It may make a determination on its own, and this I propose to do.
>
> Of the evidence adduced in the 21 percent case with respect to the service lives of equipment, that of witness O'Brien for the Canadian Pacific Railway appears to me to be the most acceptable. His evidence was that the service life of locomotives was 35 years, of freight cars 28 years and of passeng cars 34 years. I adopt the service lives as estimated by him for the purpose of calculating fair

Report of the Committee on Valuation, National Association of Railroad and Utilities Commissioners, 1949

The 1949 report of the Valuation Committee of the National Association of Railroad and Utilities Commissioners is notable in that it has reversed its prior opinion that estimated original cost is the only proper base to use in a rate case. The committee, in summing up its conclusions, points out some of the infirmities of reproduction estimates and states among other things "while investment, when correctly determined, is generally considered to be the most reliable single criteria in arriving at such a rate base" . . . continues with the following statement:

> Nevertheless, consideration should be given to present day values in arriving at a rate base and reasonable earnings on such base if justice is to be done in all cases. Such consideration may be given either directly in establishing the rate base or indirectly in fixing the rate of return. For example, assume two municipalities "a" and "b" of similar characteristics served by the same telephone utility, but with separate exchanges. Before World War II the utility found that it would be advantageous to rebuild both exchanges replacing the old equipment with new equipment of improved design. Only one exchange could be replaced at a time. At the option of the utility, exchange "a" was replaced first at low pre-war prices but it developed that exchange "b" could not be replaced until after the war and then at high post-war prices. In such a case, since the time of construction of the first exchange was at the option of the utility, over whose choice the subscriber had no control, there would be considerable justification for the same rates at each exchange. However, to fix the same rates for each exchange would require a rate base higher than net investment at one exchange and a rate base lower than net investment at the other, or corresponding differences in their respective rates of return.

The complete report merits reading and may be secured from the secretary of the N.A.R.U.C., 7413 Post Office Building, Washington, D. C., at a cost of 75 cents per copy.

Court Decisions

No outstanding cases involving valuation were decided by the U. S. Supreme Court during the year.

Report on Assignment 6 (c)

Development of Depreciation Data

The committee wishes to call attention to a judgment handed down in the Canadian Freight Rate case September 20, 1949, involving the application of the use method of depreciation for roadway and equipment property. In Canada, the Canadian Pacific Railway had been following a method which attempted to modify annual depreciation charges by the application of factors which increased or decreased the straight-line charges. Those factors were derived from the ratio of locomotive-miles, and freight and passenger car-miles for equipment, and gross ton-miles for roadway property, using as 100 percent appropriate figures for the period 1933–1946. With this base the mileages and gross ton-miles in a particular year were used to modify the charges for depreciation, depending upon the percentage, they were over or under the base period. The Board of

Report of Committee 7—Wood Bridges and Trestles

C. V. LUND, *Chairman,*
W. L. ANDERSON
W. W. BOYER
T. J. BOYLE
H. M. CHURCH
F. H. CRAMER
E. F. CROXSON
B. E. DANIELS
J. P. DUNNAGAN
N. L. FLECKENSTINE
E. L. HABERLE
NELSON HANDSAKER
R. P. HART
W. E. HEIMERDINGER
W. C. HOWE
J. C. JACOBS
R. E. JACOBUS
B. E. JACOCKS
C. S. JOHNSON
R. P. A. JOHNSON
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W. H. O'BRIEN
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H. S. RIMMINGTON
W. C. SCHAKEL
A. H. SCHMIDT
F. E. SCHNEIDER
F. W. SMALL
R. L. STEVENS
F. L. THOMPSON
A. M. WESTENHOFF
W. C. WILDER

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revision and deletion of Manual material .... page 432

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.
   No report.

3. Specifications for design of wood bridges and trestles.
   Progress report, presented as information, including revisions of specifications. page 433

4. Improved design of timber trestles, collaborating with Committee 17.
   No report.

5. Instructions for inspection of timber trestle railway bridges.
   Progress report, presented as information .... page 433

6. Methods of fireproofing wood bridges and trestles including fire-retardant paints, collaborating with Committee 17.
   Progress report, presented as information .... page 436

7. Statistics relating to wood bridges and trestles.
   Progress report, presented as information .... page 438

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
C. V. LUND, *Chairman.*

AREA Bulletin 485, January 1950.

and reasonable depreciation on equipment on a straight-line basis in a manner similar to that as proposed by respondents.

I cannot, however, agree with the contention of respondents that a fair and reasonable depreciation charge against depreciable road property may be calculated on the basis of gross retirements over the 12-year period 1936–1947 inclusive. The application of the so-called 50 percent rule is, in my view, fallacious because it assumes the existence of several basic conditions which do not in fact exist.

Exhibit 49–26 indicates that, based on annual average gross ton-miles over the period 1933–1946, the average life expectancy of depreciable road property is 60 years and shop and power plant machinery is 48 years. On a straight-line basis this would suggest rates of 1.66 percent for depreciable road property and 2.08 percent for shop and power plant machinery. Exhibit 49–10, however, indicates that the average effective rate for depreciable road property over the period 1933–1946, if user depreciation had been in effect, would have been 1.77 percent. As this rate of 1.77 percent reflects both a period of low and high use and indicates a service life of 56 years, which is in substantial agreement with the service life indicated in Exhibit 49–26, I adopt it as being a fair measure, in this instance, by which to calculate allowable depreciation charges for depreciable road property.

Having regard to the service lives of shop and power plant machinery as indicated by the experience of Class 1 United States roads, and having regard to the contention of respondents a 40-year service life and a rate of 2.50 percent appears to be a reasonable measure of depreciation charges for shop and power plant machinery.

Report on Assignment 7

Revisions, and Interpretations of ICC Accounting Classifications

H. N. Halper (chairman, subcommittee), H. D. Barnes, S. H. Barnhart, J. P. Ferris, W. M. Hager, A. H. Meyers, B. H. Moore, M. G. Pettis, J. H. Roach, H. B. Sampson, P. J. Schmitz, J. N. Smeaton, J. R. Traylor, J. L. Willcox.

This is a progress report presented as information.

The Bureau of Accounts of the Interstate Commerce Commission has issued the following ruling of interest to engineers since this committee's last report (Proceedings, Vol. 50, 1949, page 476):

Issued September 1, 1949

Case A–188.—This case directs that the cost of a car, not self-propelled, which is equipped with an oil-fired steam boiler, diesel-driven generator, air compressors, battery charging equipment, should be included in Account 54, "Passenger-train cars," for the reason that such units are auxiliary to passenger train cars which they serve.

Report on Assignment 1

Revision of Manual

Nelson Handsaker (chairman, subcommittee), W. W. Boyer, B. E. Daniels, R. P. Hart, W. E. Heimerdinger, C. S. Johnson, J. V. Johnston, W. O. Nelson, W. A. Oliver, W. L. Peoples, O. C. Rabbitt, W. C. Schakel.

Your committee recommends the following changes of text now appearing in the Manual:

Page 7–63

Value of Treated Timbers in Wood Bridges and Trestles

Delete the entire item.

Page 7–64

Merits of Galvanized Iron Fastenings for Wood Trestles

Delete the material now in the Manual, including title, and substitute the following:

USE OF PROTECTIVE COATINGS FOR IRON AND STEEL FASTENINGS FOR WOOD BRIDGES

1. Plain iron or steel fastenings will ordinarily outlast untreated timber. Creosote oil, whether straight or in coal-tar or oil mixtures, will retard corrosion of embedded metal fastenings.

2. Galvanizing or other protective coating on iron or steel fastenings is not warranted if the fastenings are to be entirely embedded in untreated or creosote treated timber or if the metal is to be exposed only to ordinary weathering.

3. When metal fastenings are not to be completely embedded and are to be exposed to salt water, brine drippings, or unusually corrosive atmosphere, consideration should be given to the use of galvanizing or to some other protective coating on the exposed metal. As the limits within which protectively coated metal is economical are not well established, local experience should be investigated.

Page 7–65

Use of Lag Screws in Trestle Construction

Delete the entire item.

In addition to the preceding items, which are covered by specific recommendations, your committee has given some time to the study of revision of the subject of inner guard rails and guard timbers for wood bridges and trestles, printed on page 7–65 of the Manual. A draft of a proposed revision has been submitted to Committee 5 and to Committee 15 for their review and criticism and these data are being assembled. The committee seeks information on observed performance of inner guard rails and will appreciate such additional comments and reports as other members of the Association may contribute.

Report on Assignment 3

Specifications for Design of Wood Bridges and Trestles

J P. Dunnagan (chairman, subcommittee), W. L. Anderson, T. J. Boyle, F. H. Cramer, E. F. Croxson, W. C. Howe, R. P. A. Johnson, W. D. Keeney, J. M. Montz, H. S. Rimmington, F. E. Schneider, R. L. Stevens, A. M. Westenhoff, W. C. Wilder.

Your committee recommends the following revisions to the Specifications for Design of Wood Bridges and Trestles for Railway Loading: page 7–118, section 301.

Revise the second and third paragraphs to read as follows:

In locations of more extreme exposure than "occasionally wet but quickly dried," and where serious depreciation is more apt to occur, a further reduction in the working stresses for extreme fiber and compression should be made.

Where timber is treated by creosoting or other process rendering it decay resistant, the working stresses for continuously dry may be used except in compression perpendicular to the grain and for joists and planks continuously submerged.

Your committee offers as information a table which shows the allowable loads in pounds on one common bolt loaded at both ends, (three-member joints), to present basic design data given in paragraph 307 and Tables 707 and 708 of the specification in convenient form for the more usual condition of exposure, "occasionally wet but quickly dried;" adjustments for bolts loaded on one end (two-member joints) is given in footnotes to the table.

Report on Assignment 5

Instructions for Inspection of Timber Trestle Railway Bridges

J. R. Showalter (chairman, subcommittee), W. L. Anderson, F. H. Cramer, J. P. Dunnagan, N. L. Fleckenstine, R. F. Jacobus, J. R. Kelly, W. B Mackenzie, F. W Madison, C. E. Peterson, A. Price, F. W. Small, A. M. Westenhoff, W. C. Wilder.

Foreword

This is a progress report, presented as information. It is the purpose of these instructions to describe the manner of inspecting a timber bridge; no attempt is made to set up the organization nor fix the responsibility or the functioning of the various members of the organization.

1. General

The method of inspecting timber regardless of its location in the structure follows:

(a) Make a careful surface inspection of each timber for cross grain, tension or horizontal shear failures that may have developed from uneven bearing, original defects or other causes.

(b) Test each timber for soundness especially at points of contact with other timbers, ground, or low water line and where end grain bears on a sill or cap.

For treated timber, a test shall be made by sounding with the knob end of an inspection bar or light weight hammer, using care to avoid injuring or disfiguring the fiber. If a hollow or dead sound results determine the nature and extent of the defect by boring, preferably with an increment borer. Bore holes where possible, so water can drain and carefully plug with treated wood.

For untreated timber, a test may be made by sounding with the knob end of an inspection bar or light weight hammer, also by probing with the pointed end of an

(b) Observe the condition of embankment at the bridge ends for fullness of crown, steepness of slopes and depth of bulkheads. Note whether the track ties are fully ballasted and well bedded.

(c) Record the weight and condition of the rail and inside guard rail, also the condition of the rail joints and fastenings. Note the size and condition of the tie plates.

(d) Where the track is out of line or surface, the location, amount and probable cause should be determined.

D. Superstructure

(a) Ascertain the size, spacing and uniformity of bearing of the ties. Note whether they are treated or untreated and the condition as to soundness, mechanical wear, spike killing and other defects.

(b) Determine the size, condition and security of anchorage of the guard timber. Note whether it is treated or untreated.

(c) Inspect all walks, railings and refuge bays, noting the condition as to soundness and security of fastening devices.

(d) Where a ballasted deck is used, ascertain the condition of all timber for soundness. Note if any members are broken or have moved out of proper position and if all fastening devices are functioning properly. Note whether the ballast is clean and in full section.

(e) Examine all stringers for soundness and surface defects. Note size and kind, whether treated or untreated and the number used in each panel. Note if the bearing is sound and uniform, if all stringers are properly chorded and securely anchored and if all shims and blocking are properly installed. Note whether packers or separators are used and the condition of all chord bolts.

(f) Note and report the presence of any wires, cables, pipe lines or other attachments which are foreign to the bridge structure.

E. Substructure

(a) Make a careful examination of all piles and posts for soundness, noting particularly the condition at the points of contact with the caps, girts, bracing, sills and the ground or water line.

(b) Examine all bents and towers for plumbness, settlement, sliding and churning, giving an accurate description of the nature and extent of any irregularities. Note particularly whether the caps and sills have full and uniform bearing on the supports.

(c) Record the number and kind of piles or posts in the bents or towers. Note the uniformity of spacing and the location of any stubbed or spliced member, especially if the bridge is on a curve or the bent is more than 15 ft. in height.

(d) Ascertain whether all bents and towers are properly sway, sashed and tower braced and girts and struts are applied as needed.

(e) Examine all fastening devices for physical condition and tightness.

(f) Observe the action of the bridge under the movement of trains, where practicable, in order to better evaluate the riding condition and soundness of the structure.

F. Fire Protection

(a) Note whether the surface of the ground around and beneath the structure is kept clean of grass, weeds, drift and other combustible material.

(b) Where rust resisting sheet metal is used as a fire protection covering for deck members, note the condition of the metal and fastenings.

inspection bar using care to avoid any unnecessary injury or disfiguring of the wood. Note the feel and sound when struck by the bar, the appearance of the fiber and all decayed or otherwise unsound wood, which should be trimmed away to sound timber.

(c) Make a careful surface inspection of the timber and adjacent ground surface for evidence of termites, carpenter ants, marine borers or other destructive insects.

(d) Make an inspection on new work, where timber is treated, of all field cuts for exposed untreated wood.

2. Details of Inspection

The bridge inspector's notes for each bridge shall be written while at the structure after a careful examination has been made covering the following points:

A. Identification

(a) Division or subdivision
Name of inspector and members of inspection party
Date of inspection
(b) Bridge number
Name of nearest station and mile post location
Age and type of structure
Total length, height and number of panels

(c) Number the bents, towers, spans or panels in each bridge in the direction in which the mile post numbers increase, starting with the dump bent as No. 1.

Number the piles in each bent or tower and stringers in each panel from left to right, when facing in the direction in which the mile post numbers increase.

B. Waterway

(a) Observe if the opening appears adequate for the drainage area, is free of obstructions such as drift, vegetation, displaced revetment stone or old pile stubs. Note whether the channel is stable, filling, deepening or subject to scour, and if public or private improvements have altered the general condition in any way. Measure and record the distance from base of rail to ground line at each bent. Measure and record high water mark if obtainable. If heavy or accumulated drift is troublesome during high water ascertain the type, such as logs, trees, ice, etc., and observe if the drift of such intensity as to force bridge out of line and/or break piling.

(b) Note whether the structure or a portion thereof is used as an underpass. Make an examination and report any damage that has occurred from inadequacy of vertical or horizontal clearance.

(c) Note if protection work is required, or cleaning and straightening of the channel is necessary. Note whether the bent alinement obstructs or deflects the normal flow and if a revetment or deflection dikes are needed.

(d) Note evidence that would indicate the presence of any buried cable, conduit, tile or pipe lines crossing under the bridge, giving the panel location together with size and use.

C. Track

(a) State whether track is level or on a grade and if alinement is tangent or curved. If on a curve, note how the superelevation is provided, whether by cutoff in the bents, taper in the caps or ballast section. Note the location of the track in reference to the chords for uniformity of loading.

1. Metal Protection

Metal protection consists of covering the deck partially or completely with sheets of No. 24 or heavier gage galvanized iron fastened with heavy galvanized roofing nails. The estimated cost of this type installation ranges from $2.25 to $3 per linear foot, depending on coverage of the structure.

The objections to this type of protection are that it tends to rust and deteriorate from refrigerator car drippings, loosens and rattles under vibration caused by traffic, and makes inspections and repairs difficult.

2. Coatings

Several railroads, particularly one in the West, have developed and used rather extensively a method of covering the exposed wood surfaces with a special patented asphalt compound which gives promise of being especially fire resistant.

The most effective results with this method are obtained by first cleaning the surface to be treated so that it is free of dust and dirt, and then applying a bituminous primer coat with brush or spray to a reasonably heavy film, being careful to fill all cracks and crevices, and cover all corners and angles so that no wood surface is left exposed.

A second coating is immediately applied, being approximately a 3/16-in. layer of the proprietary asphalt compound which contains asbestos fibers and gilsonite. Finally, there is spread over the hot compound a cover of either crushed washed stone or clean gravel from ⅛ in. to ⅜ in. in size. The stone or gravel in this application provides the fire protective element. This method of protection can be applied by hand with mop or brushes, or by spray. The recommended arrangement for off-track equipment, if a spray is used is to have a 100-psi. compressor with a long air supply line (to avoid frequent moving of the compressor) and two pumps operating on 30 to 40 psi. air pressure. This arrangement will provide one pump for the primer, and one for the second coat, and will thus obviate the necessity of cleaning out of the supply line immediately after the application of the primer, and prior to the second coat, which is required if only one pump is used. The cost of this protection varies from $0.75 to $1 per linear foot.

The objection to this method of protection is that timber so treated cannot be used again, as it cannot be sawed to size. It also makes inspection and repairs more difficult.

Another flame retardant coating, which it is believed has definite possibilities, and which at present is being tested on wooden open deck trestles, consists of a specially processed bituminous material into which various inerts are properly pigmented, producing a heavy grit mastic. This flame and fire retardant grit mastic is best applied with a spray, and with experience the sprayer can control the coating thickness required, thus eliminating the necessity of applying two coats. The application is made without heating.

The coatings described can be applied and bond equally well on treated or untreated surfaces, except that in the case of creosoted timber, application should not be made until the timber has aged at least one year after treatment.

As to fireproofing paints, the subcommittee has not learned of any being manufactured at the present time that have proved sufficiently durable for outside use.

3. Impregnation

Impregnation includes the use of various salt solutions applied at treating plants. The treated wood, in addition to being made fire resistant, may be given protection against decay and termite attack, depending on the type of treatment. Notable among the salt solutions used by commercial wood preserving plants is chromated zinc chloride.

(c) Note if any other method of fire protection has been used such as fire retarding salts, external or surface protective coatings, or fire wall. Record such apparent observations which are pertinent to physical condition and effectiveness of such protective applications.

(d) Where water barrels are provided note the number, condition, if filled and if buckets for bailing are on hand. If sand is used, note whether bins are full and in condition to keep the sand dry.

(e) Note if timber, particularly top surfaces of ties and stringers in open deck bridges, is free from frayed fiber, punk wood, or numerous checks.

3. Notes on Recommended Practices

The inspector's outline of repairs should be based on the following recommended practices:

(a) Safety should be the first consideration.

(b) Posting of the outside piles shall not be permitted on bridges, on curves where bents exceed 12 ft. in height or on tangents where bents are over 20 ft. in height.

(c) On high speed track where traffic is heavy, not more than two posted piles in any one bent shall be permitted. If more than two piles are poor, all piles should be cut off to sound wood below ground line and a framed bent installed or the piles redriven.

(d) All posts should be boxed, in addition to toe nailing, to prevent buckling.

(e) When individual caps, sills, braces or struts have become weakened beyond their ability to perform their intended function, renewal is the only remedy.

(f) When only an individual stringer is materially deteriorated, an additional stringer may be installed, inside or outside of the chord, to aid the weakened member.

(g) Where piles are decayed at the top they may be cut off and double capped. A single pile may be corbelled.

(h) Shimming of stringers to provide proper surface and cross level should be with single shim under each chord. If possible avoid multiple shimming.

Report on Assignment 6

Methods of Fireproofing Wood Bridges and Trestles

Including Fire-Retardant Paints Collaborating with Committee 17

J. V. Johnston (chairman, subcommittee), J. P. Dunnagan, E. L. Haberle, W. C. Howe, J. C. Jacobs, H. J. Kerstetter, J. C. Korte, L. J. Markwardt, T. K. May, W. O. Nelson, W. L. Peoples, O. C. Rabbitt, H. S. Rimmington, W. C. Schakel, F. E. Schneider, F. W. Small.

A large number of the railroads of this country have been canvassed by your committee to ascertain current practices on the subject assignment, and this report is submitted as information.

On the majority of railroads it has been the policy to replace open deck trestles with ballasted decks as rapidly as possible, thereby decreasing the danger of their damage or destruction by fire. However, it is not possible always to make such a change because of limitations imposed by clearance or economy. So it seems that many railroads will continue to have a large number of open deck bridges and trestles, some of which are in remote and isolated localities with the ever present danger of loss by fire.

The following methods are used in providing fire protection on open deck bridges and trestles.

Five reported they had no timber trestle in service, 16 reported having no untreated trestle, and 8 no treated trestle. Additional reports are being currently received. Some roads did not reply to all items, and replies to a few items in the questionnaire were too varied or indefinite to permit of tabulation.

This report is submitted as information.

SUMMARY

(Replies from 47 railroads, except Item 2, 52 railroads)

1. Track-feet of timber trestles in service:	*Branch Line*	*Main Line*	*Total*
(a) Untreated open deck	1,236,358	939,367	2,175,725
Untreated except bents	48,048	96,251	144,299
Untreated stringers only	274,361	149,869	424,230
Untreated other	3,161	536	3,697
(b) Treated open deck	838,839	791,904	1,630,743
(c) Treated ballasted deck	517,650	1,673,853	2,191,503
(d) Treated protected deck (80 percent reported as sheet metal)	490,863	136,226	627,089
Totals	3,409,280	3,788,006	7,197,286

2. Mileage of reporting railroads (operated).

United States	151,567	(67 percent of total in U. S.)
Mexico	8,751	
Total	160,318	

3. Types of timber trestles currently used, or considered standard construction:	*Number of railroads reporting* *Branch Line*	*Main Line*
(a) Untreated open deck	9	6
(b) Treated open deck	28	11
(c) Treated ballasted deck	3	18
(d) Treated protected deck	1	1
(e) Not standard	6	12

4. (A) Number of railroads whose policy is to replace untreated timber trestle with:

(a) Untreated timber	2
(b) Treated timber	17 (Branch lines only—2 included)
(c) Steel structures	2
(d) Concrete structures	8 (Main line only—2 included)
(e) No established policy	9

(B) Number of railroads whose policy is to replace treated timber trestle with:

(a) Treated timber	21 (Branch lines only—2 included)
(b) Steel structures	2
(c) Concrete structures	12 (Main line only—2 included)
(d) No established policy	10

5. Number of railroads using following species of bridge timber and piling:	*Timber*	*Piling*
Southern pine	14	24
Fir	13	8
Pine and fir	14	2
Fir and oak	3	
Mexico and Oregon pine	1	
Oak and pine		6
Cedar		1
Oak		3
Pine and cypress	1	
Spruce		1

Two eastern railroads have drafted specifications covering combination decay and fire resistant treatments. The use of this method has not been too successful as a fire preventive because of the leaching where used on wood trestles or bridges. The specifications referred to above recommend that where leaching may be anticipated a self-extinguishing sealer compound of high boiling pitches, trichlorobenzine, and chlorinated thinners be applied by air pressure in the treating cylinder after the material has been treated for fire resistance.

4. Fire Alarm Systems

Fire alarm systems involve the installation of fusible link detectors, that are connected with the signal and communication systems, so that in case of fire the block signals will show a warning indication, and the nearest telegraph operator will receive notification so that maintenance of way forces may be assembled to combat the fire. At the present time comparatively few railroads have installed such detectors at other than strategic or isolated locations. The cost of this system varies considerably, depending on the signal work involved, with an average cost estimated at approximately $2 per linear foot.

It has been established that the most frequent cause of timber trestle or bridge fires is the dropping of hot cinders from ash pans. However, the dieselization program will substantially reduce this hazard. The next most frequent causes of fires are, in the order named—hot slivers from brake shoes, fusees dropped by trainmen and grass fires.

The conclusion reached after a review of all information obtained at this time is that the majority of railroads prefer to replace open deck trestles and bridges with ballasted decks as rapidly as possible, and to take all ordinary precautions against fires, such as keeping decks clear of combustible material, cutting brush, weeds, and grass under and around the structures, which represent a very heavy yearly expense. The use of unrefined borax as a weed killer has been used experimentally with gratifying results. The estimated annual saving in the use of this chemical over the cost of scalping by hand has been reported by others to be at least $0.77 per linear foot, based on one application of chemical applied at a rate of 12 lb. per 100 sq. ft. and a cost of $0.32 per linear foot of trestle for each scalping, when three cleanings are required annually.

The maintenance of sound timber, which is most important, the use of water barrels, sand boxes, foamite, or other fire extinguishers, and the installation of fire breaks are recommended practices and are shown in the Manual on pages 7–66 to 7–68, incl. The loss from trestle or bridge fires has not on the whole been considered serious enough on most railroads to justify large annual expenditures for the application and maintenance of special fireproofing protection on open deck structures; however, in those territories where fires are frequently experienced such protection may be warranted in the interest of safety, and the prevention of property loss and loss of traffic.

Report on Assignment 7

Statistics Relating to Wood Bridges and Trestles

A. L. Leach (chairman, subcommittee), W. L. Anderson, J. P. Dunnagan, Nelson Handsaker, W. E. Heimerdinger, C. S. Johnson, L. P. Kieth, W. O. Nelson, O. C. Rabbitt, J. R. Showalter.

Under this assignment your committee issued a questionnaire to AAR member railroads requesting information regarding their practices and standards pertaining to timber trestles. The following statement summarizes replies from 52 railroads reporting.

Report of Committee 15—Iron and Steel Structures

R. W. MABE,* *Chairman,*
P. E. ADAMS
H. A. BALKE
FRANK BARON
J. E. BERNHARDT
E. S. BIRKENWALD
R. T. BLEWITT
M. BLOCK
H. F. BOBER
F. H. BOULTON, JR.
R. N. BRODIE
V. R. COOLEDGE
R. P. DAVIS
W. E. DOWLING
W. N. DOWNEY
C. E. EKBERG
E. M. GLAROS
G. V. GUERIN, JR.
O. E. HAGER
SHORTRIDGE HARDESTY
A. R. HARRIS
R. B. HENNESSY
S. C. HOLLISTER
N. E. HUENI
M. L. JOHNSON
JONATHAN JONES
R. L. KENNEDY
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M. B. LAGAARD
C. T. G. LOONEY
F. H. LOVELL
J. F. MARSH
F. M. MASTERS
D. V. MESSMAN
K. L. MINER
N. W. MORGAN
C. T. MORRIS
CORNELIUS NEUFELD
N. M. NEWMARK
B. J. ORNBURN
O. K. PECK
J. L. BECKEL,**
Vice-Chairman,
R. E. PECK
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W. S. RAY
C. A. ROBERTS
G. E. ROBINSON
M. A. ROOSE
J. F. SALMON
C. H. SANDBERG
T. C. SHEDD
C. E. SLOAN
H. F. SMITH
G. L. STALEY
H. C. TAMMEN
J. P. WALTON
C. EARL WEBB
W. M. WILSON
L. T. WYLY
R. W. YOUNG

Committee

* Died June 10, 1949. **Succeeded Mr. Mabe as Chairman.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Revisions of Specifications for Steel Railway Bridges and other parts of Chapter 15, submitted for adoption and publication in the Manual .... page 443

   Revision of Specifications for Movable Railway Bridges, presented as information .... page 445

2. Fatigue in high strength steels; its effect on the current Specifications for Steel Railway Bridges.

   No report.

3. Design of expansion joints involving iron and steel structures, collaborating with Committee 29.

   No report.

4. Stress distribution in bridge frames—floorbeam hangers.

   Progress report, presented as information .... page 470

5. Design of steel bridge details.

   No report.

6. Preparation of steel surfaces before painting.

   No report.

Bulletin 485, January 1950.

	Timber	Piling
6. Number of railroads purchasing bridge timber under the following grading rules:		
(a) AREA		10
(b) West Coast Lumbermen's Association		10
(c) Southern Pine Association		9
(d) SPA and WCLA	9	
(e) Railroad rules	2	
(f) Various	4	

7. Design working stresses currently being used:

	Number of railroads reporting		
	Pine	Fir	Pine and Fir
(a) Fiber stress in bending:			
Psi.			
1400	3	7	1
1600	7	3	5
1800	2	–	–
Other	3	2	2
(b) Horizontal shear			
Psi.			
100	3	6	–
120	6	5	6
Other	3	2	2
(c) Compression perpendicular to grain:			
Psi.			
Under 240	1	–	1
240–280	4	9	3
280–320	1	1	1
Over 320	7	1	1

(d) Impact used: 39 none, 4 various

8. (a) Kind of structural failures experienced, not associated with or resulting from decay:	Number of railroads reporting	
	Stringers	Caps
Cross grain and splitting and horizontal shear	22	18
Crushing	9	8
Splitting and crushing	—	7
None	14	12

	Number of railroads reporting
(b) Most prevalent type of failure, not associated with decay:	
Crushing	13
Cross grain	5
Caps splitting	5
Stringers splitting	4
9. (a) Is timber (stringers in particular) inspected at the mill?	
Yes	37
No	5
Both mill and at destination	4
(b) Is this service performed by railway company inspectors, or by established inspection bureau?	
Railway company inspectors	29
Inspection bureau	6
Both	7
10. (a) Is treatment done at a railroad treating plant or by others?	
Railroad plant	9
Railroad owned plant operated by others	5
Treatment by others	31
(b) Is timber being incised?	
Yes (fir timber)	27
No (includes 3 using fir)	17
Yes (ties only)	1

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), J. L. Beckel, R. P. Davis, O. E. Hager, Jonathan Jones, C. T. Morris, C. H. Sandberg, G. L. Staley, J. P. Walton.

The committee recommends for adoption the following revisions of the Specifications for Steel Railway Bridges:

203—page 15-6

Delete the following words in the second line of the first paragraph:

"or that shown in Fig. 1503. The load that gives the larger stress shall be used."

Delete Fig. 1503.

204 (a)—page 15-7

Change the first line to read:

Where an open or ballasted track is carried on transverse steel beams without stringers,

Add a new sentence ahead of the last sentence to read:

The load *P* shall be assumed distributed as concentrated loads on the beam under each rail.

206 (b)—page 15-8

Change the definitions of L to read:

L = length, in feet, center to center of supports for stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members)

or **L** = **length, in** feet, of the longer adjacent supported stringer, longitudinal beam, girder or truss for impact in floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns.

428—page 15-18

After the words "one wheel load" in the second sentence, add the words and punctuation:

", including 80 percent impact,"

Add the following sentence at the end of the article:

On ballasted deck girders, the wheel load, including 80 percent impact, shall be assumed to be distributed over 5 ft.

511—page 15-24

Revise the first sentence to read:

The parts of riveted members shall be well pinned, firmly drawn together with bolts and in close contact before riveting is begun.

703—page 15-30

Revise the second sentence to read:

There shall be added to the nominal weight ½ the allowed percentage of overrun in weight given in the current ASTM Specifications, Designation A 7, referred to in Article 801.

801—page 15-35

Change the word sheet in the third line to read:

steel

7. Specifications for cold riveted construction.
No report.

8. Design of metal culverts of 60-in. diameter and larger, including corrugated metal arches.
Progress report, presented as information .... page 504

9. Use of high strength structural bolts in steel railway bridges.
Progress report, presented as information .... page 506

THE COMMITTEE ON IRON AND STEEL STRUCTURES,
J. L. BECKEL, *Chairman.*

Ralph W. Mabe

Ralph W. Mabe was born on February 1, 1902 at Corryton, Tenn. He completed three years of civil engineering at the University of Tennessee, after which from July 1922 to June 1924, he served as draftsman successively with the Knoxville Power & Light Company, Knoxville, Tenn., Dodge Brothers Motor Corporation, Detroit, Mich., and the Studebaker Corporation, Detroit, Mich. Except for an interval of one year during 1928 and 1929 when he was civil engineer of the Blue Diamond Coal Company, Knoxville, Tenn., he served as draftsman and structural designer in the City of Knoxville, Tenn., engineering department from June 1924 to March 1930. He then worked for the Cincinnati Union Terminal Company as structural designer until 1933, when he became senior structural engineer in responsible charge of the railroad bridge section of the design department of the Tennessee Valley Authority, Knoxville, Tenn.

While with the Authority for almost ten years, Mr. Mabe took numerous advanced courses in concrete design and structural design, conducted by the University of Tennessee in cooperation with the Tennessee Valley Authority Training Division.

Mr. Mabe joined the Nashville, Chattanooga & St. Louis Railway in April 1943 as bridge engineer, was promoted to senior assistant engineer in December 1947 and was made assistant chief engineer on September 16, 1948, in which capacity he served until his untimely death by airplane accident on June 10, 1949.

Shortly after joining the Association in 1943, Mr. Mabe became active in its committee work, serving on the Committee on Iron and Steel Structures and the Committee on Impact and Bridge Stresses until his death. He was primarily identified with the work of the Committee on Iron and Steel Structures, of which he was vice-chairman from 1946 until he became chairman in 1949.

He was also a member of the American Society for Testing Materials.

Paragraph 8, third line: substitute barrel for barrels

Paragraph 8, 26th line: substitute "Wg.W." for "W.W."

Paragraph 9 (f): At the end of the fourth item add the words "and, if so, how much?"

Paragraph 9 (g): Add between the first and second items:

Approximate temperature at the time of measurement.

Paragraph 9 (k), add the following words to the end of the first item:

"and with the aid of a mirror, if necessary."

Paragraph 9 (n) add a new last item:

Bottoms of end stiffeners

Paragraph 9 (p) (9) Insert a new item reading: "Clearance at each end when locked," after the eighth item reading: "Clearance through a complete cycle of operation."

The following partial draft of the Specifications for Movable Railway Bridges is submitted as information for the purpose of soliciting comments and criticisms prior to submission a year hence for adoption and publication in the Manual.

SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES

FOREWORD

The purpose of these specifications is to formulate specific and detailed rules for the design and manufacture of movable railway bridges, as a guide to both the designer and the shop, rather than to confine the specifications to a statement of principles or to limit them to rules defining the duties of the contractor. The intention is to describe the best general practice for standard railways of the United States and Canada, and to advance the causes of good design and workmanship. The requirements of light and branch railways and foreign practice have not been considered.

CONTENTS

Pages 15–121 to 15–127

Rules for Rating Existing Iron and Steel Bridges

Last year your committee presented as information revised rules for review and criticism by the Association before adoption and publication in the Manual. During the past year, no comments or suggestions have been received, and accordingly the revised rules are now offered for adoption to replace the existing rules in the Manual, identically as they appear in the Proceedings, Vol. 50, pages 428 to 432, incl., except for the following typographical corrections:

On page 428:

Change 1949 to 1950

Change the caption I GENERAL to 1. General, shifting it to the margin.

On page 429, Article 107, Impact (B) 2.

Change the third line to read:

"straight line variation from full effect as synchronous speed to 0.2 of the"

Shift the reading matter below the expression $\sqrt{\frac{12}{d+D}}$ to line up with the rest of paragraph 2 and insert:

"for static live load"

after the words "for dead load and" and before the words "placed in the position. . . ."

On page 430, Article 109. Wind

Change (a) to read:

For girder spans 1½ times the vertical projection of the span.

Change the first sentence below (c) to read:

This loading is predicated on the reasoning that when the wind velocity exceeds 70 mph. a train will operate at reduced speed, if it operates at all.

On page 431, Article 113. Permissible Stresses

In the sentence following the formulas for axial compression, change the word "comparison" to read "compression."

Indent for paragraphing the sentence starting:

"Compression in extreme fibers of rolled shapes, . . ."

On page 432

Indent the first line for paragraphing.

Shift to margin the line starting: "If the members are packed. . . ."

Indent for paragraphing the two lines each starting with the word "Shear."

Pages 15–134 to 15–138

Large Rivets

Reapproved except for the first paragraph in small print which is revised to read:

The requirements for rivets in these specifications are identical with the current requirements of the American Standards Association, American Standard, Large Rivets, ½-in. Nominal Diameter and Larger, designated ASA B–18.4.

Pages 15–139 to 15–144

Instructions for the Maintenance Inspection of Steel Bridges

Reapproved except for the following editorial revisions:

Paragraph 5, fifth line to read:

"sending copy to the division engineer, division superintendent, general bridge inspector, bridge engineer and the chief engineer, giving the safe"

I PROPOSALS AND GENERAL REQUIREMENTS

101. General

The structural design and the mechanical and electrical design will be furnished by the company, unless it is stated in the invitation for bids that such designs, or specified portions of them, are to be furnished by the contractor.

The current Specifications for Steel Railway Bridges of the American Railway Engineering Association shall apply to movable bridges except as provided otherwise herein.

102. Responsibility

Unless otherwise provided, the contractor shall be responsible for the complete installation of the superstructure and the operation of the moving span as far as pertains to the materials, workmanship, and erection, and the designing of parts and details which are not covered by the proposal plans. The contractor shall furnish and erect the structure ready for operation and to receive trains, except for such parts as are specified to be furnished or installed by the company.

103. Time of Opening

The normal time for opening the bridge after the ends are released shall be as specified on the proposal drawings for both the main and the auxiliary powers.

104. Machinery Drawings

The contractor shall make an assembly drawing and detail drawings of the machinery. These drawings shall be so complete that the machinery parts may be duplicated without reference to patterns, other drawings, or individual shop practice.

105. Machinery Design

If the machinery design is prepared by the contractor, he shall furnish complete design calculations for all parts of the machinery and shall include therein curves showing the torques to be exerted at the shaft of each main and auxiliary operating motor and engine as follows:

(a) For acceleration and for retardation.
(b) For frictional resistance.
(c) For any unbalanced condition of the bridge.
(d) For the wind loads.
(e) For the greatest resultant combinations of resistances acting at one time under the various design conditions herein specified. The torque for starting friction shall not be combined with the torque for acceleration. Torque curves showing the rated full load torque and the maximum starting torque of the motor or engine shall be superimposed on this curve.

Where operation is by electric motor, these calculations shall include a diagram on which there are shown the required speed-torque curves for the various steps of resistance which are to be provided. On this diagram there shall also be shown the overload relay setting and the speed torque curves for operation of the span under Cases A, B and C of Article 308.

INFORMATION TO BE FURNISHED

The engineer shall specify, or the drawings shall indicate, the following information in accordance with the listed articles of the specifications: *Article*

1. What is the live load to be used? 203*
2. Is the alinement straight or curved? 105*, 208*
   If curved, what is the degree of curve? What is the superelevation of the outer rail? What speed should be used in the design?
3. What is the rate and the direction of grade on the bridge? 446*
4. Type of track anchorage on moving span and approaches ....
5. What are the conditions at the site? 2*
   Furnish plans showing the general dimensions and conditions governing the design of the structure:

   Length of spans
   Types of spans
   Number and spacing of tracks
   Angle of skew
   Type of floor
   Required horizontal and vertical clearances for channel span
   Type and dimensions of fenders

6. What kind of shop paint will be approved? 544*
7. A copy of the contract form 102
8. Will there be separate contracts for the different parts of the superstructure? 102
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* Article numbers marked thus refer to Specifications for Steel Railway Bridges.

The contractor shall also furnish six bound copies of a similar booklet for the mechanical equipment, which shall include lubricating charts showing the locations of all lubricating fittings and other points of lubrication.

113. Classification of Parts

The parts of the bridge shall be classified as follows and, unless otherwise stipulated, paid for as indicated:

(a) Structural carbon steel, by the pound.
(b) Special structural steels, by the pound for each class specified.
(c) Machinery, by the pound.
(d) Counterweight sheaves, by the pound.
(e) Trunnions and their bearings, by the pound.
(f) Segmental castings and track castings, by the pound.
(g) Wire ropes and sockets, by the pound.
(h) Balancing chains, by the pound.
(i) Metal in counterweights, by the pound.
(j) Concrete in counterweights, by the cubic yard.
(k) Reinforcing steel, by the pound.
(l) Gasoline, gas, and oil engines and tanks, a lump sum.
(m) Electrical equipment, a lump sum.
(n) Houses for machinery and operators, a lump sum.
(o) Railway deck and track, by the linear foot of full-width deck.
(p) Miscellaneous lumber, by the thousand feet board measure.
(q) Items not clasified in the foregoing.

Payment quantities shall be determined as follows:

Classes (a) and (b) by the provisions of Article 701 of the specifications designated in Article 101.

Class (c), (d), (e), (f), (g), (h), and (i), by scale weight; except that for Classes (c), (d), (e) and (f), scale weight in excess of 5 percent above the computed weight shall not be included.

Class (k) by the computed weight of plain bars of the specified sizes.

Classes (j), (l), (m), (n), (o), (p), and (q) by the engineer's measurement.

114. Parts Included in Classes

Parts included in the different classes shall be:

(a) *Structural Carbon Steel,* and (b) *Special Structural Steel.*—In addition to the moving span, any parts of rolled, forged, or cast steel which can be fabricated by the common shop methods of punching, reaming, drilling, boring, shearing, planing, bending, etc., usual for stationary structures.

Rim girders in swing bridges, segmental girders in rolling bascule bridges and the girders on which they roll, parts supporting the machinery, shim plates for adjustment of the machinery, machinery housings, counterweight frames, counterweight trusses, counterweight boxes, operating struts, towers, steel framing and plates in houses for machinery and operators, handrails, stairways and ladders, shall be classified as structural steel.

Members composed wholly of carbon steel shall be classified as structural carbon steel. Members composed wholly (except possibly for rivets) of silicon steel, nickel steel, or other special structural steel shall be classified as such. Members or parts containing two or more classes of structural steel shall be classified and paid for according to the

106. Weight and Center of Gravity

The contractor shall determine the weight and (where necessary) the location of the center of gravity of the moving span, including parts attached thereto; also of the counterweights, including their frame work. These determinations shall be based on weights carefully computed from shop plans. The computations, accompanied by the weight bills, shall be submitted to the company in form for verification.

107. Houses

The contractor shall furnish and build the machinery house or houses. The house or houses for the operator and the signal devices shall be built by the contractor or the company, as may be stipulated.

108. Signals and Interlocking

The company will furnish and install the railway signal system, including the master lever and the devices necessary for interlocking the signal system with the moving span. The contractor shall furnish and install the devices necessary for interlocking the parts of the bridge machinery with each other and for connection to the master lever. The operating machinery and the electrical parts shall be so designed that the signal system may readily be installed and attached.

109. Warning Lights

The contractor shall furnish and install (including wiring) on the moving span and piers, navigation lights and other signals required by the United States government or other authorities, and shall provide suitable means of access to such lights.

110. Wrenches

Two sets of wrenches to fit heads and nuts of all bolts for the machinery shall be furnished by the contractor, together with suitable work bench, pipe vise, and suitable wall racks for the storage of equipment and spare parts.

111. Defects

If any defects due to faulty workmanship or erection, or defective material, or due to any design prepared by the contractor, are found within one year after the date of acceptance, the contractor shall remedy such defects at his own expense. If necessary, the company may remedy such defects at the expense of the contractor.

112. Wiring Diagrams, Operator's Instructions, Electrical and Mechanical Data Booklets, and Lubrication Charts

The contractor shall furnish six bound copies of a booklet containing descriptive leaflets and drawings covering all items of the electrical equipment, with catalog numbers indicated; printed or typewritten statements prepared by the manufacturers of the equipment covering the proper methods of adjusting, lubricating, and otherwise maintaining each item; speed-torque-current curves for the span-operating motors for each point of speed control; a concise statement of the necessary operating functions in proper sequence; a detailed description of the functions of each item in connection with the various operating steps; reduced photostatic copies of all wiring and conduit diagrams and drawings of the control bench and switchboards; and a list of spare parts furnished. The booklet shall contain a table of contents and shall designate each wire and item of equipment by the numbers on the wiring diagrams.

(l) *Gasoline, Gas, and Oil Engines and Tanks.*—Gasoline or oil-driven engines with tanks, compressors, starters, and interrelated piping to and including clutch shaft but not clutch for delivery of power and to but not including valve for delivery of air.

(m) *Electrical Equipment.*—High-voltage equipment and transformers as specified, the switchboard and control deck with their attachments, and electrical parts beyond (whether on or off the moving span), such as motors, controllers, electric brakes, solenoids, circuit breakers, relays, contactors, switches, synchronizing and leveling equipment, limit switches, blow-outs, cut-offs, meters, trolley poles, trolley wheels and contact shoes, lamps, navigation lights and signals, electric heaters, conductors, submarine and other cables, and conduits and their fittings, as specified for the operation of the moving span and accessories, and the lighting and heating of the houses.

Unless otherwise noted in the invitation to bid, this item and this contract shall include no parts or appurtenances of the signal interlocking system except that the switchboard shall be of ample size to accommodate the interlocking equipment as specified by the engineer.

(n) *Houses for Machinery and Operators.*—All parts of such houses except steel framing and plating if any; also all furniture, heaters other than electric, cranes, fire extinguishers, supplies, and similar items, as specified in the invitation to bid.

(o) *Railway Deck and Track.*—The complete timber deck, footwalks at deck level, and permanent track, with all permanent fastenings in place, except specially fabricated track rails, special rail joints and rail locks; also sheet metal or other track coverings and fire stops.

Unless otherwise specified in the invitation to bid, the company will furnish all of these materials and their fastenings f.o.b. bridge site, ready for installation, and the contractor shall unload, place and fasten same for the unit price per linear foot under this class.

(p) *Miscellaneous Lumber.*—Any lumber not allocated to another class by the foregoing definitions, together with nails, bolts and other fastenings. Measurement of lumber shall be based on nominal sizes for the lengths in place.

115. Optional Requirements

Whenever hereinafter optional requirements are stated, the determination shall be made by the engineer, and shall be indicated (a) in the invitation to bid if bidders are to prepare plans or (b) on the plans prepared by the company which accompany the invitation to bid.

II GENERAL FEATURES OF DESIGN

201. Types

Movable bridges preferably shall be of the following types:

(a) Swing.
(b) Single leaf bascule.
(c) Vertical lift.

The proposal drawings will show, or the engineer will determine, the following:

The type of movable bridge.
For swing bridges, the type of center.
For bascule bridges, the type of bascule.
For vertical lift bridges, the type of tower, the location of the prime mover, and the provisions for keeping the moving span level.

Pin-connected trusses shall not be used.

computed ratios of weights of the several classes of steel contained therein; except that the heads of carbon steel rivets used in a member composed partially or wholly of a special steel shall be included in the computed weight of the lowest-price class of steel in the member or part.

(c) *Machinery*

Sheaves
Wheels
Winding drums
Spools
Center-pivot stands
Discs
Pivots
Tread plates
Rollers
Roller treads
Roller guides
Shafts
Axles
Gears
Racks
Worm gearings
Pedestals
Bearings
Lubrication devices
Screws
Wedges
Wedge bases
Toggles
Levers
Cranks
Pipes
Bars
Eccentrics
Hooks
Cables and wires for push-pull devices
Deflector castings and plates
Buffers
Pistons and their cylinders
Capstans
Brakes (unless part of electrical equipment)
Whistles
Bells
Indicators
Bridge locks
Rail locks
Especially fabricated track rails
Special rail joints
Wrenches

Pins about whose axes the connecting members rotate
Equalizing devices and other fastenings for wire ropes (except sockets)
Bolts attaching machinery parts to each other and to their supports
Similar parts which require machine shopwork and which are not included in any other class.

Machinery parts attached to structural parts shall be separately weighed before attachment thereto.

(d) *Counterweight Sheaves.*—Cast or built sheaves, together with their shafts, and bearings, and their connecting bolts.

(e) *Trunnions and Bearings.*—Trunnions for moving leaves and counterweights of bascule bridges, together with their bearings, sleeves, supporting pedestals, and their connecting bolts.

(f) *Segmental Castings and Track Castings.*—Segmental castings and track castings for rolling lift bridges, together with their connecting bolts.

(g) *Wire Ropes and Sockets.*—Wire ropes and their sockets, together with the socket pins.

(h) *Balancing Chains.*—Chains and their fastenings used for balancing the counterweight ropes.

(i) *Metal in Counterweights.*—Cast iron used as counterweights; also scrap metal used to increase the unit weight of counterweight concrete.

(j) *Concrete.*—Concrete or mortar used in counterweights, including concrete balance blocks, and concrete in pockets of column bases and similar places. No deductions shall be made for enclosed reinforcing steel or scrap metal.

(k) *Reinforcing Steel.*—All reinforcing bars and mesh for concrete. Unless otherwise provided, no direct payment will be made for clips, spacers, ties, chairs, or other fastenings and supports for reinforcing steel, but their cost shall be included in the price per pound paid for reinforcing steel.

or rooms containing electric control equipment shall have thermal insulation. There shall be at least one window in each side of the house. All windows shall be glazed with wire or other shatter-proof glass. Openings shall be large enough to admit passage of the largest unit of machinery.

The floor shall be built of concrete, steel, or other fireproof material, as specified. It shall be smoke tight and have a non-slip surface. Floors in rooms containing electrical equipment such as switchboards and control desks shall be covered with linoleum, asphalt tile, or rubber mats.

If the bridge is hand-operated, or if the operator is not located in the machinery house, a house shall be provided for him. The type of construction shall be the same as that specified for the machinery house, except that for hand-operated bridges with the house located off the bridge structure, fully fireproof construction will not be required.

If practicable, the operator's house shall be located so as to afford a clear view of operations on the railway and on the waterway.

Provisions shall be made for the heating apparatus to be installed in the operator's house by the company or by the contractor, as may be specified.

If stipulated, a hand-operated overhead traveling crane, of sufficient capacity for handling the heaviest piece of machinery, shall be installed in the machinery house.

208. Stairways, Walks, and Elevators

Metal stairways, platforms, and walks with railings shall be provided to give safe access to the operator's house, machinery, trunnions, counterweights, lights, bridge seats, and all points requiring lubrication. Ladders may be installed only where stairways are not feasible, and shall be provided with safety cages where required by codes. In vertical lift bridges, ladders and walks shall be installed to give access to the moving span in any position from either tower. Hand railings shall be made of wrought iron, galvanized copper-bearing steel, or other rust-resistant metal pipe, not less than 1½-in. size, or of structural shapes. Stairways and ladders shall be of metal. The treads may be channels filled with concrete. In tower-drive vertical lift spans, electrically-driven elevators shall be provided in each tower if specified.

209. Materials Used

Materials in machinery and similar parts shall be as follows:

Rolled Steel or Forged Steel.—For trunnions, shafts, axles, bolts, nuts, keys, cotters, pins, screws, worms, piston rods, equalizing levers, and crane hooks.

Trunnions, shafts and axles up to 6 in. in diameter may be either rolled or forged; those of larger diameter shall be forged. Shafts larger than 3½ in. in diameter shall not be cold rolled.

Rolled Steel, Forged Steel, or Cast Steel.—For rim, segmental, and track girder treads and rollers.

Forged Steel or Cast Steel.—For levers, cranks, and connecting rods.

Forged Steel.—For pinions and rope attachments.

Cast Steel.—For pivot stands, couplings, wedges, wedge bearings, toggles, trailing wheels, end shoes, pedestals, pistons and their cylinders, buffers, eccentrics, valves, spools, winding drums, racks, tracks, gears, brake wheels, clutches, lock castings, trunnion bearings, shaft bearings and hangers, and sheaves for vertical lift bridges.

Treated Steel.—For parts which require hardening or oil tempering, such as pivots, friction rollers, ball bearings, and springs.

Bronze.—For pivot discs, worm wheels, linings of the trunnion bearings of bascule and lift bridges, linings of other large bearings carrying heavy loads, and such gears and nuts as are required to be of bronze.

202. Counterweights

The counterweights shall be sufficient to practically balance the moving span and its attachments in any position, except that there shall be small positive reactions at the supports when the bridge is seated. For vertical lift bridges having a vertical movement exceeding 40 ft., the counterweight ropes shall be balanced by chains or other devices unless otherwise specified.

Provision shall be made for unbalanced conditions in the design of the machinery and the power equipment.

Provision shall be made for independent supports for the counterweights of vertical lift bridges.

203. Alining and Locking

Movable bridges shall be equipped with suitable mechanism to surface and aline the bridge and track accurately and to fasten them securely in position, so that they cannot be displaced either horizontaly or vertically under the action of traffic. Effective end lifts shall be used for swing bridges, and span locks for bascule and vertical lift bridges. Rail locks shall be used for all movable spans.

Rail locks on movable bridges shall be designed so that they cannot be locked with the rail displaced ¼ in. or more from proper position.

Span locks on movable bridges shall be designed so that they cannot be locked unless the movable parts are within ½ in. of proper position.

The operating mechanisms of end lifts and rail locks shall be independent.

The installation shall meet the applicable requirements of the Bureau of Safety of the Interstate Commerce Commission.

204. Auxiliary Power

Power-operated bridges shall be equipped with an auxiliary source of power. This source shall be a gasoline or oil engine, a gasoline or oil-driven generator set, or hand power, as specified.

Where sources of electric power are unusually reliable, bridges may be provided with two independent sources or electric power, instead of auxiliary power. In such instances there shall be emergency motors with their control entirely independent of that provided for normal operation, or each set of operating machinery shall be provided with two motors, either of which shall be capable of operating the bridge under overload through an entirely independent control.

205. Interlocking

The bridge operating devices shall permit interlocking with the signal system. They shall be so interlocked with each other that the operations, both for opening and closing the bridge, must be performed in predetermined order, and so that the movable span, tracks, and switches within interlocking limits are locked in proper position.

206. Insulation of Track

The connections of parts in contact with the track shall be such as to prevent all possibility of short circuiting of signal or other circuits.

207. Houses For Machinery and Operators

If mechanical power is to be used for operating the bridge, a suitable house or houses shall be provided for the machinery and the operator. Houses shall be large enough for easy access to all machinery, and shall be fireproof and weatherproof. Houses

parts (as in the case of swing span trusses, vertical lift bridge trusses and towers, and supports for bascule trunnions), shall be increased 20 percent to allow for impact or vibratory effect. This impact allowance shall not be combined with live load stresses.

Stresses in structural parts caused by the machinery or by forces applied for moving or stopping the span shall be increased 100 percent as an allowance for impact.

The end floor beams of the moving span and the adjacent floor beams of the fixed spans shall be proportioned for a concentrated load of 90,000 lb., without impact, on each track, in addition to the specified live load and impact.

Allowance has been made for impact in trunnions, wire ropes, wire rope attachments, and machinery parts in the unit stresses specified herein for such parts.

303. End Ties

The ties which support the rail joint shoes at the ends of the moving span and at the adjacent ends of the fixed spans shall be supported throughout their length, so that they will not be subjected to bending. The supports for these ties, if other than end floor beams, shall be proportioned for a concentrated load of 90,000 lb. on each track plus 150 percent impact.

304. Reversal of Stress and Secondary Stresses

Structural members and their connections, subject to reversal of stress during the movement of the span, shall be proportioned as follows: Determine the resultant tensile stress and the resultant compressive stress, and increase each by 50 percent of the smaller; then proportion the member to resist either increased resultant stress. The connections shall be proportioned for the sum of the resultant stresses.

Secondary stresses occurring in connection with reversal of stress, and those in trusses of unusual form, shall be computed, and provided for in proportioning.

305. Wind Load and Ice Load

In proportioning the members and determining the stability of swing, bascule, and vertical lift spans, and their towers, wind loads shall be assumed acting either transversely, longitudinally, or diagonally at an angle or 45 deg. with the bridge tangent. Exposed areas for transverse wind loads on the spans shall be determined as provided in the current Specifications for Steel Railway Bridges. Exposed areas for longitudinal wind loads on the spans shall be taken as ½ those for transverse wind, except for bascule bridges for spans when open where they shall be modified as specified below for loads acting normal to the floor. Exposed areas for transverse and longitudinal wind loads on houses and counterweights shall be their vertical projections. Exposed areas for transverse and longitudinal wind loads on towers and their bracing shall be the vertical projections of all columns and bracing not shielded by the counterweights and houses. For diagonal wind, the equivalent simultaneous transverse and longitudinal wind loads shall be taken as 70 percent of the values for winds acting transversely and longitudinally, respectively.

The following wind loads and unit stresses shall be used in proportioning the members and determining the stability:

Moving Span Closed.

(a) 30 lb. per sq. ft. on the structure and the train, combined with dead load, live load, impact, centrifugal force, and longitudinal force from trains, at 1.25 times normal unit stresses.

(b) 50 lb. per sq. ft. on the structure, combined with dead load, at 1⅓ times normal unit stresses.

Bronze or Babbitt Metal.—For the linings of journal bearings and of other rotating or sliding parts.

Weldments.—Welded assemblies of structural steel or of structural steel and cast steel may be employed instead of cast steel for such parts as may be specified in the invitation or approved by the engineer. Such weldments shall conform in all respects to the Specifications for Welded Bridges of the American Welding Society, and shall be stress-relieved before being machined. The approval of the engineer shall be obtained for all phases of the design and manufacturing procedure.

Cast iron shall be used only for the parts of motors, engines, and standard manufactured articles that are usually made of cast iron, for balancing chains for vertical lift bridges and for counterweights. Balancing chains shall be made of cast iron links connected by rust-resistant steel pins in bored holes.

210. Rail Ends

Rails at the ends of movable spans shall be mitered or cut square. Mitered rails shall retain the full thickness of the web to the points. The points shall be trailing to normal traffic where possible; otherwise they shall be trailing to traffic entering the moving span.

Where rail ends are cut square, they shall be connected by sliding sleeve or joint bars, or by easer rails to carry the wheels over the opening between the ends of the bridge and approach rails.

Where rail ends are mitered, they shall be provided with seats that will secure them effectively against transverse displacement, and with devices that will bring the mitered surfaces nearly into contact and hold them in such position.

211. Protection of Traffic

Railway traffic shall be protected at movable bridges in accordance with the current Requirements for the Protection of Traffic at Movable Bridges of the American Railway Engineering Association.

III LOADS, UNIT STRESSES, AND PROPORTIONING OF PARTS

(a) General

301. Live Load

The live load shall be as specified in Article 203 of the current Specifications for Steel Railway Bridges of the American Railway Engineering Association.

In computing the live load stresses, the live load shall be considered as applied, either continuously or in separated parts, in such manner as to produce the maximum stresses.

302. Impact

The impact from live load shall be as specified in Articles 206 and 207 of the current Specifications for Steel Railway Bridges of the American Railway Engineering Association. For swing bridges, L shall be taken as the length of the loaded arm when only one arm is loaded, and as the total loaded length when both arms are loaded partially or wholly.

Dead load stresses in structural parts in which the stress varies with the movement of the span (as in the case of a bascule), or in parts which move or support moving

307. Machinery Resistances

In calculating the resistances to be overcome by the machinery, the resisting forces shall be reduced to a single force acting between the pinion and the operating rack, or in the operating cable. In determining this force, the following coefficients shall be used.

	For Starting	*For Motion*
For trunnion friction		
(a) One or more complete rotations	0.135	0.09
(b) Less than one complete rotation	0.18	0.12
For manually operated bridges, the coefficients for motion given above shall be increased 25 percent		
For friction on center discs	0.15	0.10
For rolling friction of bridges having rollers with flanges, or built-up segmental girders	0.009	0.006
For collar friction at ends of conical rollers	0.15	0.10
For 180-deg. bending of wire ropes, for each sheave, the coefficient of direct tension in rope	$0.3\frac{d}{D}$	$0.3\frac{d}{D}$
(d = diameter of rope in inches, D = diameter of sheave in inches).		
For rolling friction of solid cast rollers without flanges:		
(a) In contact with one surface only	$\frac{0.008}{\sqrt{r}}$	$\frac{0.008}{\sqrt{r}}$
(b) In contact with two surfaces	$\frac{0.008}{\sqrt{r}}$	$\frac{0.008}{\sqrt{r}}$
(r = radius of roller in inches).		

In designing the machinery for holding the span against the wind pressure specified in Article 306, and for determining the required capacity of the brakes both for holding the span against this wing pressure and for stopping the span when in motion, 0.4 of the above mentioned coefficients for motion shall be used. Rope stiffness, solid roller friction, and machinery friction shall be disregarded. In determining the effect of the brakes on the machinery while stopping the span, full machinery friction shall be considered as effective.

For sliding friction between plane surfaces intermittently lubricated, the coefficient of friction shall be taken as 0.08.

308. Machinery Losses

In computing the machinery losses between the operating rack, or the operating rope, or a similar point, and the prime mover, the following coefficients shall be used:

For journal friction	0.05
For efficiency of any pair of gears, journal friction not included	
Spur gears and herringbone gears	0.98
Bevel gears, collar friction included	0.90
For efficiency of worm gearing, collar friction included	$\frac{Np}{Np + R}$

where N = number of threads of lead of worm
p = circular pitch of teeth on wheel, and
R = radius of worm.

309. Brakes, and Machinery Design for Braking Forces

Bridges operated only manually shall be provided with one set of brakes.

Mechanically operated bridges, except as otherwise specified by the engineer, shall be provided with two sets of brakes. One set, called the motor brakes, shall be on the motor shaft, or if the prime mover is other than an electric motor, as near the shaft of the prime mover as practicable, and the other set, called the machinery brakes, shall be as near the operating ropes or racks as practicable.

Moving Span Open

(c) When the moving span is normally left in the closed position. 30 lb. per sq. ft. on the structure, combined with dead load, and 20 percent of dead load to allow for impact, at 1.25 times normal unit stresses. For swing bridges provision shall also be made for 30 lb. per sq. ft. on one arm and 20 lb. per sq. ft. on the other arm.

(d) When the moving span is normally left in the open position. 50 lb. per sq. ft. on the structure, combined with dead load, at 1⅓ times normal unit stresses. For swing bridges provision shall also be made for 50 lb. per sq. ft. on one arm and 35 lb. per sq. ft. on the other arm.

For open deck bridges, the area exposed to ice and to wind acting normal to the floor shall be taken as 85 percent of the area of a quadrilateral whose width is the distance center to center of the trusses and whose length is that of the span. For bridges with solid floors, or with footwalks, the actual exposed floor surface shall be taken.

306. Power Requirements and Machinery Design

The machinery shall be proportioned and power provided to move the span under the following conditions:

A. In the normal time for opening:

1. Bascule bridges and vertical lift bridges against frictional resistances, rope bending, unbalanced conditions (Article 202), inertia, and a wind load of 2½ lb. per sq. ft. on the area specified in Article 305, acting normal to the floor. For vertical lift spans, this wind load shall be considered to include frictional resistances from span and counterweight guides caused by horizontal wind on the moving span.
2. Swing bridges against frictional resistances, inertia, and a wind load of 2½ lb. per sq. ft. on the vertical projection of one arm.

B. In 1½ times the normal time for opening:

Bascule bridges and vertical lift bridges with an ice load of 2½ lb. per sq. ft. on the area specified in Article 305, in addition to the loads specified in A.

C. In twice the normal time for opening:

Bascule bridges and unequal arm swing bridges against frictional resistances, unbalanced conditions (Article 202), inertia, a wind load of 10 lb. per sq. ft. on any vertical projection of the open bridge, and an ice load of 2½ lb. per sq. ft. on the area specified in Article 305. For swing bridges provision shall also be made for a wind load of 10 lb. per sq. ft. on one arm and 5 lb. per sq. ft. on the other arm.

In proportioning the machinery, the actual speeds produced by the prime mover selected shall be used, rather than the specified speeds.

The torques to be exerted at the shaft of the prime mover for Conditions A, B, and C are hereinafter referred to as the normal bridge torques. The bridge torque for starting the span shall not include the torque to overcome inertia.

For bascule and swing bridges, the machinery shall also be proportioned to hold the span in the fully open position against a wind load of 30 lb. per sq. ft. on any vertical projection of the open bridge. For swing bridges, provision shall also be made for a wind load of 30 lb. per sq. ft. on one arm and 20 lb. per sq. ft. on the other arm. In proportioning the machinery for these conditions, 1.5 times the normal unit stresses may be used.

Material	*Tension*	*Compression*	*Fixed Bearing*	*Shear*
Structural carbon steel	12,000	$12{,}000-50\frac{l}{r}$	16,000	6,000
Class C_1 forged carbon steel	12,000	$12.000-55\frac{l}{r}$	16,000	6,000
Class E forged carbon steel—except keys .	14,000	$14{,}000-65\frac{l}{r}$	18,000	7,000
Class E forged carbon steel—keys			14,000	7,000
Class A forged alloy steel	16,000	$16{,}000-70\frac{l}{r}$	21,000	8,000
Hot rolled shafting and cold finished shafting (equal to Class E forged)	14,000	14,000		7,000
Cast steel	9,000	$10{,}000-45\frac{l}{r}$	13,000	5,000
Cast iron—Grade 25	2,000	10,000*	10,000	2,000
Phosphor-bronze, Class D	7,000	7,000		3,500

* For struts whose $\frac{l}{r}$ is 20 or less.

STRESS IN EXTREME FIBERS OF TRUNNIONS

	Rotation more than 90 percent	*Rotation 90 percent or less*	*Fixed Trunnions*
Class C_1 forged carbon steel	13,000	13,000	15,000
Class E forged carbon steel	15,000	15,000	17,000
Class A forged alloy steel	16,000	20,000	22,000

For stresses in rotating parts, and in frames, pedestals, and other units which support rotating parts, the computed stresses shall be multiplied by the factor K. In the following equations for K, $n =$ rpm. of rotating part.

Stresses not reversed, where rotation is always in one direction, such as torques on shafts and stresses in keys, couplings, cranks, and gears (except teeth):

$K_1 = 1.0 + 0.03\sqrt{n}$

Reversed stresses, where there is reversal of stress only upon reversal of direction of operation of the part, such as torques on shafts and stresses in keys, couplings, cranks, and gears (except teeth):

$K_2 = 1.0 + 0.03\sqrt{n}$

Reversed stresses, where there is reversal of stress during rotation of the parts, such as bending moments in shafts, and stresses in rims and spokes of counterweight sheaves, of vertical lift bridges:

$K_3 = 1.1 + 0.03\sqrt{n}$

Extreme fiber stresses in trunnions:

$K = 1.0$

314. Bearing Pressures

The following maximum bearing pressures on the diametral projected area, in pounds per square inch, for rotating and sliding surfaces shall be used:

(a) For intermittent motion with speeds not exceeding 50 ft. per min.:
Pivots of swing bridges, hardened tool steel on grade A phosphor-bronze discs 3,000
Pivots of swing bridges, hardened tool steel on grade B phosphor-bronze discs 2,500

A

Where only one set of brakes is provided, the brakes shall have sufficient capacity to stop the span in 10 sec. when it is moving at full load speed (the speed conforming to the normal time for opening) under the influence of the greatest unbalanced loads specified in Article 306, and to hold the span against the specified wind pressure.

Where two sets of brakes are provided, they shall have the following capacities:

> The motor brakes shall have sufficient capacity to stop the span in 10 sec. when it is moving at full load speed under the influence of the greatest unbalanced loads specified for Condition A of Article 306 for swing bridges, and Condition B of the same article for bascule and vertical lift bridges.
>
> The machinery brakes for vertical lift bridges and equal arm swing bridges shall have a capacity, as measured at the shafts of the motor brakes, equal to ½ that of the motor brakes. The machinery brakes for bascule bridges and unequal arm swing bridges shall be such that the combined motor and machinery brakes will have sufficient capacity to stop the span in 10 sec. when it is moving at full load speed under the influence of the greatest unbalanced loads specified in Article 306, and to hold the span against the specified wind pressure.

The coefficient of friction for braking shall be taken at 0.25. If practicable, the pressure per square inch on the rubbing surface of the brake shall not exceed 30 lb., and the product of the pressure per square inch on the rubbing surface times the velocity of the brake wheel rim in feet per minute shall not exceed 90,000.

Provision shall be made in the design of the machinery (including operating ropes, if any) for the stresses caused by either the motor brakes or the machinery brakes, at normal unit stresses. Provision shall also be made for combined action of both sets of brakes at unit stresses 50 percent greater than normal.

For calculating the strength of the machinery parts under the action of manually operated brakes, the force applied at the extreme end of a hand lever shall be assumed at 150 lb. and the force applied on a foot pedal shall be assumed at 200 lb.

310. Machinery Supports

In the design of structural parts subject to stresses from machinery or from forces applied for moving or stopping the span, due consideration shall be given to securing adequate stiffness and rigidity. Beams subject to such stresses shall preferably have a depth not less than ⅛ of the span; and if shallower beams are used, the section shall be increased so that the deflection will not be greater than if the above limiting depth had not been exceeded. Deflections shall be investigated sufficiently to insure that they will not interfere with proper machinery operation.

311. Anchorage

Anchor bolts or other anchorages that take uplift shall be designed at normal unit stresses to carry and engage a mass of masonry the weight of which is 1½ times the uplift.

312. Unit Stresses in Structural Parts

Structural parts shall be proportioned by the current Specifications for Steel Railway Bridges of the American Railway Engineering Association.

313. Unit Stresses in Machinery Parts

The following unit stresses in pounds per square inch shall be used for machinery and similar parts:

where f = unit extreme fiber stress in tension or compression.
S = unit shear.
d = diameter of shaft at the section considered.
M = simple bending moment computed for the distance center to center of bearings.
T = simple twisting moment.
$K_2 = K_1 = 1.0 + 0.03\ \sqrt{n}$ (See Art. 311)
$K_3 = 1.1 + 0.033\ \sqrt{n}$ (See Art. 311)
n = rpm. of shaft.

If a shaft, trunnion, or axle has one keyway at the section where the maximum stresses occur, f and S shall be considered to be increased by 1/6; if two keyways, by ¼.

318. Bolts in Tension

Bolts in tension shall be designed by assuming the effective area of the threaded portion to be

$$A = A_n - \tfrac{1}{4}D$$

where A = effective area of threaded portion in square inches.
A_n = net area at root of thread in square inches.
D = nominal diameter of threaded portion in inches.

319. Machinery Design

The machinery parts shall be designed for the normal bridge torques specified in Art. 306, using the normal unit stresses herein given.

They shall also be so proportioned that the normal unit stresses will not be exceeded by more than 50 percent, using $K = 1.0 + 0.03\ \sqrt{n}$ (Art. 313), under the following forces and conditions.

(a) Holding the span against 30 lb. wind, at zero speed (Art. 306)
(b) Braking, at 75 percent of Case A speed (Arts. 306 and 309)
(c) Effect of prime movers

1. Internal combustion engines, at Case A speed.
   4 cylinders or more, 125 percent of rated engine torque
   Less than 4 cylinders, 150 percent of rated engine torque
2. Electric motors (a.c. slip-ring wound rotor), at 75 percent of Case A speed.
   Torques not limited by current-limiting or time-delay control devices, and by instantaneous-acting overload limit devices, 225 percent of full load motor torque.
   Torques limited by current-limiting or time-delay control devices, and by instantaneous-acting overload limit devices, 110 percent of setting of the overload limit device, but not less than 175 percent of full load torque.

(b) Special for Swing Bridges

320. Stress Combinations

The stresses in trusses or girders of swing bridges continuous on three or four supports shall be calculated for the bridge in the following conditions:

1. Bridge open, or closed with ends just touching.
2. Bridge closed with ends lifted.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.

Case II. Condition 2, dead load, ends lifted to give positive reaction equal to the maximum negative reaction of the live load and impact plus 50 percent of their sum.

Trunnion bearings and counterweight sheave bearings, rolled or forged steel on grade B phosphor bronze	1,500
Rolled or forged steel on grade C phosphor bronze	1,000
Wedges, cast steel on cast steel or structural steel	1,500
Screws which transmit motion (on projected area of thread)	200
(b) For speeds exceeding 50 ft. per min.:	
Hardened steel on grade B bronze	1,200
Rolled or forged steel on grade C bronze	600
Rolled or forged steel on babbitt metal	400
Rolled or forged steel on cast iron	400
Cross-head slides (speed not exceeding 600 ft. per min.)	50

For slow-moving journals, as on trunnions, counterweight and deflector sheave bearings, and operating drum bearings, the bearing area shall be taken as the net area, the effective areas of oil grooves being deducted from the gross bearing area.

315. Journal and Pivot Bearings

The pressure on pivots or step bearings for vertical shafts, and on journals, shall not exceed:

On pivots, $p = \frac{60{,}000}{nd}$, but not more than 900

On journals, $p = \frac{250{,}000}{nd}$, but not more than 600

On collars, $p = \frac{50{,}000}{nd}$, but not more than 200

p = pressure in pounds per square inch.
n = number of revolutions per minute.
d = diameter of pivot or journal or mean diameter of collar in inches.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given by the foregoing formulas may be doubled.

316. Pressure on Rollers

The permissible pressure in pounds per linear inch of rollers shall be

For rollers in motion	*Diameters up to 25 in.*	*Diameters from 25 to 125 in.*
Cast iron	$200d$	$1{,}000\sqrt{d}$
Cast steel	$400d$	$2{,}000\sqrt{d}$
Rolled or forged carbon steel	$400d$	$2{,}000\sqrt{d}$
Tool steel	$800d$	$4{,}000\sqrt{d}$
Hardened tool steel	$1{,}000d$	$5{,}000\sqrt{d}$
For rollers at rest		
Cast steel	$600d$	$3{,}000\sqrt{d}$
Rolled or forged carbon steel	$600d$	$3{,}000\sqrt{d}$

(d = diameter of roller in inches)

The foregoing values are for rollers and bearing surfaces of like materials. If the rollers and bearing surfaces are of unlike materials, the lower value shall be used.

317. Shafts

Circular shafts, trunnions, and axles shall be proportioned by the following formulas:

$$f = \frac{32}{d^3}\left(\tfrac{1}{2} K_3 M + \tfrac{1}{2}\sqrt{K_3^2 M^2 + K_2^2 T^2} \right)$$

$$S = \frac{16}{d^3}\sqrt{K_3^2 M^2 + K_2^2 T^2}$$

Case II. Condition 2, dead load.
Case III. Condition 3, dead load.
Case IV. Condition 2 or 3, live load plus impact.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone, plus 20 percent.
Case II with Case IV.
Case III with Case IV.

The stress sheet shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

In the proportioning of members, unit stresses 25 percent greater than the normal allowable unit stresses may be used for the combination of Case III with Case IV. Members subject to reversal of stress under this combination of cases or in consideration of this combination with any other combination shall be proportioned for the maximum tensile and compressive stresses without increase for any reversal effect.

(d) Special for Vertical Lift Bridges

325. Stress Combinations

The stresses in trusses or girders of vertical lift bridges shall be calculated for the bridge in the following conditions:

1. Bridge open.
2. Bridge closed.
3. Bridge closed, with counterweights independently supported.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.
Case II. Condition 2, dead load.
Case III. Condition 3, dead load.
Case IV. Condition 2 or 3, live load plus impact.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone, plus 20 percent.
Case II with Case IV.
Case III with Case IV.

The stress sheet shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

In the proportioning of members, unit stresses 25 percent greater than the normal allowable unit stresses may be used for the combination of Case III with Case IV. Members subject to reversal of stress under this combination of cases or in consideration of this combination with any other combination shall be proportioned for the maximum tensile and compressive stresses without increase for any reversal effect.

326. Wire Ropes

The total unit tension in counterweight ropes shall not exceed 2/9 of the specified unit ultimate strength of the rope, nor shall the unit tension from the direct load only

Case III. Condition 1, live load plus impact on one arm as a simple span.

Case IV. Condition 2, live load plus impact on one arm, bridge as a continuous girder.

Case V. Condition 2, live load plus impact on both arms, bridge as a continuous girder.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone, plus 20 percent.
Case I with Case III.
Case I with Case V.
Case II with Case IV.
Case II with Case V.

The stress sheet shall show the stresses in the different members of each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

321. End Lift Reactions

The end lifting machinery of swing bridges shall be proportioned to exert an uplift equal to the maximum negative end reaction of the live load and impact plus 50 percent of their sum.

The end bearings shall be proportioned for the maximum positive end reaction including impact.

The center wedges and supports shall be proportioned for the reaction of the live load and impact.

322. Rollers

The rollers of rim bearing or combined rim and center bearing swing bridges shall be proportioned for the dead load stresses when the bridge is swinging, and for the dead and live load and impact stresses when the bridge is closed.

In computing the load on the rollers, the rim girder shall be considered as distributing the load uniformly over a distance equal to twice the depth of the girder, back to back of flange angles. This distance shall be taken as symmetrical about the vertical through the point of application of the concentrated load.

323. End Lift Machinery

In designing the machinery parts for the end lifts of swing bridges, the methods specified for the machinery actuating the moving span shall be used.

(c) Special for Bascule Bridges

324. Stress Combinations

The stresses in trusses or girders of bascule bridges shall be calculated for the bridge in the following conditions:

1. Bridge open in any position.
2. Bridge closed.
3. Bridge closed, with counterweights independently supported.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.

401b. Rim Bearing

The load on the rim girder of a rim-bearing or combined rim and center-bearing swing bridge shall be distributed equally among the bearing points. The bearing points shall be spaced equally around the rim girder.

Rigid struts shall connect the rim girder to a center pivot firmly anchored to the pier. A strut shall be attached to the rim girder at each bearing point, and at intermediate points when required. No fewer than eight struts shall be used in any case.

The rim girder shall be so designed that the load will be properly distributed over the rollers. For calculating stresses in the girder, the loads shall be assumed to be distributed equally to all rollers. The span length shall be taken as the developed length of the girder between adjacent bearing points. This part of the girder shall be considered fixed at both ends. The girder shall be designed in accordance with the requirements for plate girders.

The lower track shall be strong enough to distribute the load on the rollers uniformly over the masonry.

401c. Combined Bearing

In a combined rim and center-bearing swing bridge, a definite portion of the load, not less than 15 percent, shall be carried to the center by radical girders attached rigidly to the center and to the rim.

401d. Shear Over Center

In swing bridges having a center truss panel, this panel shall be so designed that shear will not be carried past the center. The web members of such panel shall be strong enough, however, to make the bridge secure against longitudinal wind pressure when it is open.

V WIRE ROPES AND SOCKETS

501. Manufacturer

Wire rope shall be made by a manufacturer whose facilities and experience are approved by the engineer.

502. Diameter of Rope

The diameter of counterweight ropes shall be not less than 1 in., nor more than 2½ in.; of operating ropes not less than ¾ in.

The actual diameter of a wire rope (the diameter of the circumscribed circle) shall be measured with the rope under a tension equal to 10 percent of the ultimate strength. The amount by which the actual diameter of a rope may differ from the nominal diameter shall be not greater than the following:

Normal Dia. of Rope In.	*Undersize*	*Oversize In.*
⅝ to ¾	0	1/32
13/16 to 1⅛	0	3/64
1 3/16 to 1½	0	1/16
1 9/16 to 2¼	0	3/32
2 5/16 to 2½	0	1/8

503. Construction

All wire ropes shall be made of improved plow steel wire. All operating ropes shall be preformed wire rope.

exceed ⅛ of the specified ultimate strength. For operating ropes, the corresponding limits shall be 3/10 and 1/6.

327. Bending Stress and Permissible Load over Sheave

If a wire rope is bent over a sheave, the bending stress and permissible load on the rope shall be calculated as follows:

Let P = permissible load on rope, in pounds.
K = unit stress due to bending in extreme fiber of largest individual wire.
E = modulus of elasticity 28,500,000.
a = cross-sectional area of rope in square inches.
d = diameter of largest wire in inches.
D = diameter of sheave, center to center of rope, in inches.
S = greatest unit tension allowable.
L = angle of helical wire with axis of strand.
B = angle of helical strand with axis of rope.
c = diameter of rope.

$$\text{Then } K = \frac{0.8\, Ed\, \cos^2 L\, \cos^2 B}{D} \quad \text{(1)}$$

$$P = a\left(S - 0.8\,\frac{Ed\, \cos^2 L\, \cos^2 B}{D}\right) = a\left(\frac{S - 0.7\, Ed}{D}\right) \quad \text{(2)}$$

For rope having 6 strands of 19 equal wires each,

$$P = a\left(S - \frac{1{,}300{,}000c}{D}\right) \quad \text{(3)}$$

$$\text{assuming } d = \frac{c}{15}$$

For haulage rope, 6 strands of 7 wires each, $d = \frac{c}{9}$

328. Small Sheave over Short Arc

If a rope is in contact with a small sheave over a short arc (50 deg. or less), the actual radius of curvature of the rope may be greater than that of the sheave.

Let R = the actual radius of curvature of the rope.
θ = the angle between the directions of the rope.
W = pull on individual wire (equals P divided by the number of wires if all wires are of equal diameters).

$$\text{Then } R = \frac{d^2}{4.25 \sin \frac{\theta}{2}} \sqrt{\frac{E}{W}}$$

If R is greater than the radius of the sheave, $2R$ should be used in place of D in formulas (1), (2) and (3).

IV DETAILS OF DESIGN

The following articles have been transferred from Section II. They are numbered 211, 212, 213 and 214 in the current specifications.

401a. Center Bearing

Center-bearing swing bridges shall be so designed that when the bridge is swinging, the entire weight of the moving span is carried on a center pivot, and when the bridge is closed, the trusses rest at the center on wedges. Adjustment for height shall be provided.

The test specimens of the wire shall be subjected to a torsion test in which the distance between the jaws of the testing machine is 8 in. The number of complete successive turns of 360 deg. in one direction through which an 8-in. length wire can be twisted around its longitudinal axis without breaking or showing any signs of splitting or other defects shall be not less than the following:

Dia. of Wire In.	*Number of Turns Divided by Dia. of Wire in In.*
0.038–0.060	2.3
0.061–0.100	2.2
0.101–0.140	2.1
0.141–0.190	2.0

In this torsion test, one end of the wire is to be rotated with respect to the other end of the wire at continuous uniform speed until breakage occurs. During the test the applied tension shall be sufficient to straighten the wire. The speed of rotation shall not exceed 60 twists per minute. Such tests shall be carried out by a mechanically driven device, such as a motor or belt drive, in order to secure operation at constant uniform speed.

All of the tests specified above shall be made upon fair samples which may be taken from either end of any coil of wire, and such samples shall be taken from not less than 10 percent of the total number of coils.

The tolerance limits on diameters of like positioned wires in the strands of the wire rope shall not exceed the following value:

Dia. Wires, In.	*Total Variation, In.*
0.038–0.060	0.002
0.061–0.100	0.0025
0.101–0.140	0.003
0.141–0.190	0.0035

508. Ultimate Strength

In order to demonstrate the strength of the rope and its fastenings, test pieces not more than 12 ft. in length but with a length between the sockets equal to at least 25 rope diameters shall be cut, and shall have sockets, selected at random from those to be used in filling the order, attached to their ends. The number of test pieces shall be not less than two from each original length in which the rope is fabricated, and not more than 10 percent of the total number of finished lengths of rope to be made for the order. The test pieces shall be taken from both ends of the original lengths in which the rope is fabricated. A small zinc collar shall be cast around the rope against the end of the socket, so that any movement of the latter can be readily detected. These test pieces are to be stressed to destruction in a suitable testing machine, the first sample of each size being tested with the machine running at its slowest speed. The sockets used for these tests shall not be used in the structure. Under this stress, bright (uncoated) wire ropes shall develop the minimum ultimate strength given in the following table:

All wire ropes shall be of 6 × 25 filler wire construction with hard fiber center. Each strand shall consist of 19 main wires and 6 filler wires fabricated in one operation with all wires interlocking. There shall be four sizes of wires in each strand; 12 outer wires of one size, 6 filler wires of one size, 6 inner wires of one size, and a core wire.

Ropes shall be laid in accordance with the best practice. Every effort shall be made to obtain ropes of uniform physical properties. The ropes shall be fabricated in the greatest lengths practicable, and all similar ropes for any one bridge shall be cut from the smallest practicable number of original pieces.

504. Lay

All wire ropes, unless otherwise specified, shall be right regular lay, and the maximum length of rope lay shall be as follows:

Operating ropes —6¾ times nominal rope diameter.

Counterweight ropes—7½ times nominal rope diameter.

The lay of the wires in the strands shall be such as to make the wires approximately parallel to the axis of the rope where they would come in contact with a circular cylinder circumscribed on the rope.

505. Lubrication During Fabrication

All hard fiber centers shall be prelubricated by the cordage manufacturer. All portions of wire ropes—fiber center, wires, and strands—shall be lubricated during fabrication with a corrosion-resisting lubricant approved by the engineer.

506. Splices

No splicing of the ropes or individual strands will be permitted. Wire splices shall be securely and properly made by electric welding, and no two joints in any one strand shall be closer than 25 ft. apart, except for filler wires.

507. Wire—Physical Properties

The wire from which wire ropes are made shall be tested in the presence of an inspector designated by the engineer. Excepting that the filler wires may be made to the manufacturer's standards, and physical properties of the bright (uncoated) individual wires before fabricating into the rope shall be as follows:

The unit tensile strength shall be not less than the following:

Dia. of Wire In.	*Tensile Strength Minimum, Psi.*	*Maximum, Psi.*
0.038–0.060	238,000	268,000
0.061–0.100	230,000	260,000
0.101–0.140	225,000	255,000
0.140–0.190	218,000	248,000

The total ultimate elongation of the wires measured on a 10-in. gage length, at the breaking strength of the wire, shall be not less than the following:

Dia. of Wire In.	*Elongation Percent*
0.038–0.060	1½
0.061–0.100	1¾
0.101–0.140	2
0.141–0.190	2¼

In the foregoing tests, the specimens shall be at least 15 in. long, and free from bends and kinks.

specified minimum ultimate strength, the entire lot shall be rejected, and new ones, made of stronger material or to a heavier design, shall be furnished.

Sockets shall be painted in the shop as specified for structural steel.

512. Facilities for Testing

The manufacturer shall provide proper facilities for making the tests, and shall make, at his own expense, the tests required. Tests shall be made in the presence of an inspector representing the engineer.

513. Length

The length of each counterweight rope from inside of bearing to inside of bearing of sockets shall be determined, and a metal tag having the said length stamped thereon shall be securely attached to the rope. While being measured, each rope shall be twisted to the correct lay, it shall be supported throughout its length in a straight line at points not more than 25 ft. apart, and it shall be under a tension of 12 percent of its ultimate strength. (This corresponds approximately to the direct load on the rope.) A variation from the required length, of not more than one 0.005 part of the length, will be allowed.

The contractor shall verify the exact lengths to which the counterweight ropes shall be manufactured.

Each rope shall have a stripe painted on one side along its entire length at the time the measurement of length is made. This stripe shall be straight after the rope is erected.

Ropes shall be suitably marked or tagged for identification for proper erection.

514. Operating Ropes

Ends of operating ropes when not provided with sockets shall be seized and shall have the wires composing the ropes welded together. This seizing shall be removed prior to making the attachments of the ropes to the drums and take-ups. Lengths of the operating ropes shall be determined by the contractor, and shall be such as to give minimum lengths of three turns on the drum and take-ups for zero stress in the ropes.

515. Shipping

All ropes shall be shipped on reels, the diameter of which is not less than 25 times the diameter of the rope, unless permission to ship in coils is specified in the order. The rope shall be removed by revolving the reels.

ULTIMATE STRENGTH OF IMPROVED PLOW STEEL ROPE, 6 STRANDS BY 19 WIRES

Dia. of Rope in In.	*Approximate Area of Section $0.4D^2$*	*Ultimate Strength Psi.*	*Entire Rope Lb.*
½	0.100	216,000	22,000
⅝	0.156	210,000	33,000
¾	0.225	206,000	46,000
⅞	0.306	205,000	63,000
1	0.400	203,000	81,000
1⅛	0.506	203,000	103,000
1¼	0.625	201,000	126,000
1⅜	0.756	200,000	151,000
1½	0.900	199,000	179,000
1⅝	1.056	198,000	209,000
1¾	1.225	197,000	242,000
1⅞	1.406	196,000	275,000
2	1.600	195,000	312,000
2⅛	1.806	193,000	349,000
2¼	2.025	192,000	390,000
2⅜	2.256	191,000	432,000
2½	2.500	190,000	476,000

509. Rejection

If the physical properties of the rope or of its individual wires fall below those specified, the entire length from which the test pieces were taken shall be replaced by the manufacturer with a new length, the physical qualities of which conform to those specified.

510. Prestressing

Each counterweight rope shall be prestressed to 35 percent of its ultimate strength given in Art. 508. This load shall be applied one time only to the rope, and shall be held on the rope for a period of not less than 4 hours.

511. Sockets

All sockets used in connection with wire ropes shall be forged, without welds, from solid steel. The finished sockets shall conform to the requirements of the current Specifications for Carbon Steel Forgings for General Industrial Use, ASTM Serial Designation A235, Class C1. In every case the dimensions shall be such that no part under tension shall be stressed higher than 48,000 psi. when the rope is stressed to its specified ultimate strength. The sockets must be attached to the rope by a method which is reliable and which will not permit the rope to slip appreciably in its connection.

Under the test specified in Art. 508, the movement of the rope in the socket, when the rope is stressed to 80 percent of its specified ultimate strength, shall not exceed 1/6 the nominal diameter of the rope. If a greater movement should occur, the method of attachment shall be changed until a satisfactory one is found.

The sockets shall be stronger than the rope with which they are used. If a socket should break during the test specified in Art. 508, two others shall be selected and attached to another piece of rope and the test repeated, and this process shall be continued until the inspector is satisfied of their reliability, in which case the lot shall be accepted. If, however, 10 percent or more of all the sockets tested break at a load less than the

TABLE I: LIST OF RIVETED TRUSS SPANS WITH FAILURES IN FLOOR BEAM HANGERS

FIG. NO.	NO SPANS	SPAN LENGTH	TRUSS TYPE	NO. OF TRK'S	YEAR BUILT	YEAR FAILED	NO. OF FAILURES	FLOOR BEAM HANGER SECTION	LOCATION OF FAILURE: CRACK, ℄ TRACK, ℄ SPAN — LEGEND FOR LOCATION	LOCATION OF FAILURE: POINT OF FAILURE		NET UNIT STRESS FAILURE SECTION ksi MAX.	MIN	NOTES
11	1	114'-8½	THRU	1	1910	1937	1	2 ⊏ 10 X 20# LACED		MAIN MAT. ABOVE FL. BM.	I.S.	23.31	2.13	
-	1	160'-0	THRU SKEW	1	1928	1941	2	4 Ls 6X4X7/16 TIE PLS.	NOT THRU ANY RIVET HOLE	" " " " "	"	16.6	3.7	GROSS AREA
13	1	113'-9	DECK	1	1917	1941	1	4 Ls 6X4X3/8 1 PL.10 X 3/8	1 CRACK U1 L1	ALL AT INSIDE ANGLE LEG		55.6	3.0	
12	2	157'-3	"	1	"	"	8	4 Ls 6X4X3/8 1 PL 14½X3/8	4 CRACKS U1 L1	CONNECTED TO TOP GUSSET		54.6	3.70	
									4 CRACKS U3 L3	THRU LOWEST RIVET LINE				
	1	85'-6	PONY	1	1900	1942	1	4 Ls 4X3X3/8 1 PL.9X5/16	1 CRACK U1 L1		I.S.	14.57	1.29	AXIAL LOAD ONLY
	1	85'-6	"	1	1900	1944	3		3 CRACKS U1 L1		I.S.	14.57	1.29	
	1	125'-6	THRU	1	1900	1947	1	4 Ls 4X3X3/8 1 PL 9X5/16	1 CRACK U3 L3		I.S.	18.06	2.28	
	6	96'-0	"	1	1903	1945	15	4 Ls 4X3X3/8 1 PL 7X5/16	15 CRACKS U1 L1		I.S.	18.15	1.85	
	1	100'-0	"	1	1904	1937	1	4 Ls 5X3½X3/8 1 PL 9X7/16	1 CRACK U1 L1		I.S.	16.71	1.89	
	1	100'-0	"	1	1905	1946	1	4 Ls 5X3½X5/8 1 PL 9X7/16	1 CRACK U1 L1		I.S.	9.69	1.12	
	1	120'-0	"	1	1899	1939	1	4 Ls 4X3X3/8 1 PL 9X5/16	1 CRACK U1 L1		I.S.	17.66	2.28	AXIAL LOAD
14	15	120'-0	"	1	1902		22	4 Ls 4X3X3/8 1 PL 9X5/16	4 CRACKS 6 CRACKS ALL IN*		10 O.S.	19.47	1.55	
									3 CRACKS 4 CRACKS U1 L1		7 I.S.	16.47	1.55	
15								4 Ls 4X3X3/8 1 PL 9X5/16	1 CRACK U3 L3		O.S.	18.50	1.70	
	1	122'-0	THRU	1	1918	1942	1	4 Ls 6X3½X3/8 1 PL.15½X3/8	1 CRACK U1 L1		O.S.	12.52	1.56	
	1	122'-9¾	"	1	1912	1939	1	4 Ls 4X4X3/8 1 PL.12X3/8	ALL 4 ANGLES OF U1L1 CRACKED		O.S.	19.65	1.72	
	1	125'-0	"	1	1905	1941	2	4 Ls 4X3X7/16 1 PL.8½X7/16	2 CRACKS U1 L1	LOWEST RIVET LINE	I.S.	15.16	1.94	
	1	127'-0	"	1	1905	1945	4	4 Ls 4X3X7/16 1 PL 8½X7/16	4 CRACKS U1 L1	IN TOP GUSSET	I.S.	15.22	1.94	
	1	130'-0	"	1	1905	1941 & 1943	2	4 Ls 4X3X7/16 1 PL.8½X7/16	1 CRACK U1 L1		O.S.	17.00	1.96	
									1 CRACK U1 L1		I.S.	15.28	1.80	
	3	131'-0	THRU SKEW BRIDGE A	1	1902	1947	5	4 Ls 5X3½X3/8 1 PL.11½X3/8	1 CRACK 1 CRACK ALL IN*		2 O.S.	21.87	3.30	TRUSS DEFLECTION NEGLECTED
									1 CRACK U2 L2		1 I.S.	17.93	2.80	
	3	131'-0	THRU SKEW BRIDGE B	1	1902	1947	8	4 Ls 5X3½X3/8 1 PL.11½X3/8	1 CRACK 2 CRACKS ALL IN*		3 O.S.	21.87	3.30	
									3 CRACKS U2L2		3 I.S.	17.93	2.80	
	1	156'-6	THRU SKEW	1	1902	1947	1	4 Ls 5X3½X7/16 LACED	1 CRACK U2 L2		I.S.	18.38	2.42	
	2	153'-4	THRU	1	1902	1947	3	4 Ls 5X3½X7/16 "	1 CRACK 1 CRACK IN U2 L2		2 O.S.	23.76	2.33	
								4 Ls 3½X3½X3/8 "	1 CRACK CENTER SUBHANGER		1 I.S.	11.84	1.25	
	3	155'-0	THRU	1	1902	1947	4	4 Ls 5X3½X7/16 "	1 CRACK ALL IN		1 O.S.	24.41	2.85	
									2 CRACKS 1 CRACK U2L2		3 I.S.	19.29	2.57	ONE TRACK LOADED
16	2	163'-4½	THRU	2	1910	1947	3	4 Ls 6X4X5/8 1 PL.14½X3/8	3 CRACKS U2L2		O.S.	17.49	2.77	
	51		TOTALS				91							

*LOCATION OF STARTING POINT OF REMAINING FAILURES UNKNOWN.
FIG. 3 HANGERS FAILED IN 2 Ls
1 " " IN 4 Ls

FIG. BRIDGE A - IN ADDITION TO ABOVE, 2 FAILURES IN ANGLES NOT IDENTIFIED
BRIDGE B - 1 FAILURE AT BOTTOM OF GUSSET NOT THRU A HOLE
2 HANGERS FAILED IN 2 OUTSIDE ANGLES

NOTE: ALL STRESSES ARE COMPUTED EXCEPT FOR 160' THRU SKEW SPAN WHERE LL+I WERE MEASURED BY AAR RESEARCH OFFICE

Report on Assignment 4

Stress Distribution in Bridge Frames—Floorbeam Hangers

C. H. Sandberg (chairman, subcommittee), J. E. Bernhardt, S. C. Hollister, J. F. Marsh, F. M. Masters, N. M. Newmark, C. Earl Webb, L. T. Wyly.

Foreword

The floorbeam hanger research project consists in the investigation of the causes and remedies for the failures in floorbeam hangers in railway bridges. It is being conducted at the Purdue University Engineering Experiment Station under the direction of L. T. Wyly, research professor of structural engineering and head of department. Administration is by Dr. A. A. Potter, director of the Engineering Experiment Station and dean of engineering, and by Professor R. B. Wiley, head of the School of Civil Engineering and Engineering Mechanics. The project is sponsored financially by the Association of American Railroads. The program was initiated upon the recommendation of AREA Committee 15—Iron and Steel Structures, and is supervised by the subcommittee on stresses in bridge frames—floorbeam hangers. This is a cooperative project and the research office of the Association of American Railroads, under the general direction of G. M. Magee, research engineer, and E. J. Ruble, structural engineer, assists in and advises regarding the work.

This report summarizes the progress to date on this project. The report was written by Professor Wyly.

Program

The work program of the project consists of the following:

1. A fact-finding survey of failures which have occurred and the analysis of these failures.
2. Study of the stress distribution in the hangers of selected bridges under service loads, both static and dynamic, and under service conditions, obtained by strain measurements in the field.
3. Study of the stress distribution, under controlled laboratory conditions, in components and models of the hangers and of the static and fatigue strength of these components.

Survey and Analysis of Failures

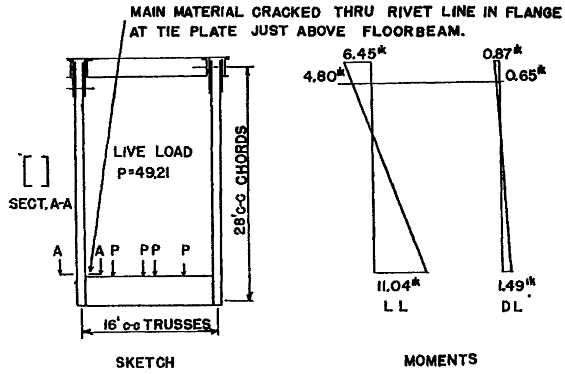
Early in 1947, a questionnaire was sent by the chairman of Committee 15 to the bridge engineers of AAR member railroads, asking for detailed information regarding any failures in floorbeam hangers. Later the same year, a similar letter was sent by Mr. Magee to the chief engineers of these railroads. Fifty replies were received and ⅓ of these reported a total of 170 failures in 83 spans of 50 bridges.

I. Report on Hanger Failures in Riveted Truss Spans

1. Digest

This report presents a summary of the information submitted by various railroads concerning failures in floorbeam hangers of riveted truss spans; gives the results of a detailed stress analysis; classifies the failures according to location.

Summary data and typical failure locations are shown in Tables 1, 2 and 3 and in Figs. 1 to 6, incl. Diagrams showing distribution of the failures plotted against unit stress on net section, years of heavy loading, year built, and total years of service are



RANGE OF STRESS - AXIAL + BENDING ksi

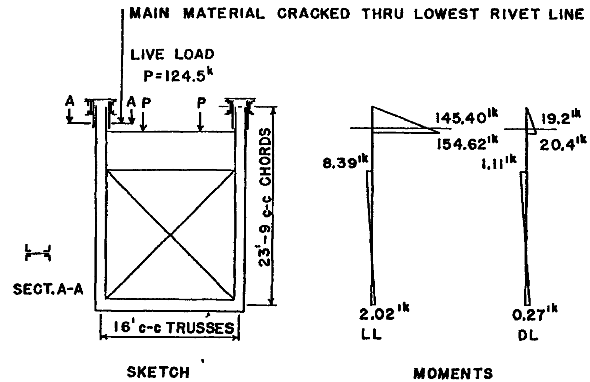
	FAILURE SECT. A-A GROSS AREA	FAILURE SECT. A-A NET AREA	LOWEST RIVET LINE IN U_1 GUSSET GROSS AREA
MAX. D+L+65.7 % I	19.3	23.3	17.0
MIN. D	1.8	2.1	1.6

GENERAL DATA
SPAN - 114'-8¼ T.R.T.
BUILT - 1910
HANGER FAILURE - 1937
ESTIMATED NO. CYCLES CAUSING ABOVE L L STRESS - 66,000

SECTION
2 ⊏ 10" X 20#

REFERENCE: FIG. 11

FIG. 1
SUMMARY DATA
STRESS ANALYSIS OF FLOORBEAM HANGER
114'-8¼ THRU RIVETED TRUSS



RANGE OF STRESS - AXIAL + BENDING ksi

	FAILURE SECTION A-A GROSS AREA	FAILURE SECTION A-A NET AREA
MAX. D+L+64.9% I	44.7	54.6
MIN. D	3.0	3.7

GENERAL DATA
SPAN 157'-3 D.R.T.
BUILT 1917
HANGER FAILURE 1941
NO. OF FAILURES 9
ESTIMATED NO. CYCLES CAUSING ABOVE LL STRESS - 180,000

SECTION
4 Ls 6 x 4 x ⅜
1 PL 14 x ⅜

REFERENCE: FIG. 12

FIG. 2
SUMMARY DATA
STRESS ANALYSIS OF FLOORBEAM HANGER
157'-3 DECK RIVETED TRUSS

TABLE 2 FAILURES BY LOCATION

TRUSS TYPE / FAILURE LOCATION	THRU SPANS: LOWEST RIVET TOP GUSSET	THRU SPANS: ABV. FL. BM.	DECK SPANS
OUTSIDE ANGLE	27		
INSIDE ANGLE	45	3	9
UNKNOWN	7		
TOTAL	79	3	9
TOWARDS ℄ SPAN	43		
TOWARDS END SPAN	25		
CENTER PANEL	2		4
UNKNOWN	9	3	5
TOTAL	79	3	9

TABLE 3 FAILURES BY HANGER SECTIONS

SECTION	SQUARE	SKEW	TOTAL	AT U_1 GUS.	AT FL. BM.	NO SPANS
LACED	1		1		1	1
TIED		2	2		2	1
LACED	7	1	8	8		.6
WEB PL.	67	13	80	71	9	43

given in Figs. 7 to 10, incl. Typical details of hangers, location of failures, computed unit stresses and other pertinent information are shown in Figs. 11 to 16, incl.

The outstanding facts brought out by this report are:

(a) Only 12 of the hangers failed at the point of greatest computed bending stress, the other 79 all failing in the net section through the line of the lowest rivets connecting the members to the top chord gussets. See Tables 1, 2 and 3.

(b) These 79 failures occurred apparently as a result of a certain number of repetitions of load producing a calculated unit stress on the net section at point of failure ranging from about 9 to 24 ksi.,* and the greatest number occurred after being stressed to about 18 to 22 ksi. See Table 1 and Fig. 7.

(c) All failures occurred after relatively few repetitions of stress. In most cases, the estimated number of loadings under heavy engines was about 30,000 to 40,000.

(d) The dead load stress in these members was about 2 ksi., so that the range of stress due to the addition of live load was relatively much larger than is the case with most truss members.

2. Foreword

A detailed report on the failures in the riveted truss spans is being sent by Mr. Magee to the chief engineers of all member railroads. This report includes figures showing details for each hanger failure. Additional copies of this report to the chief engineers are available upon request to the research engineer, AAR.

* ksi. = kips (1000 lb.) per sq. in.

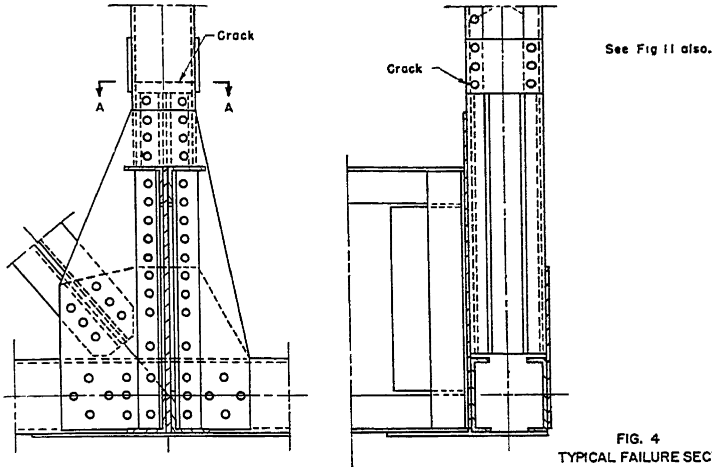


FIG. 4
TYPICAL FAILURE SECTION
114'-8¼ RIVETED THRU TRUSS SPAN
1 FAILURE

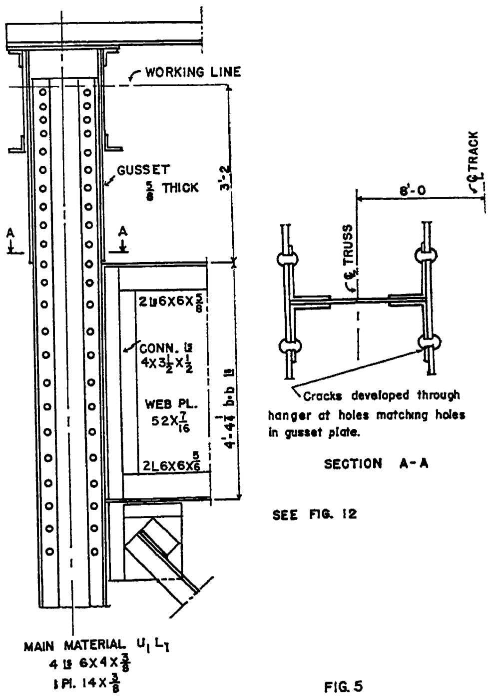
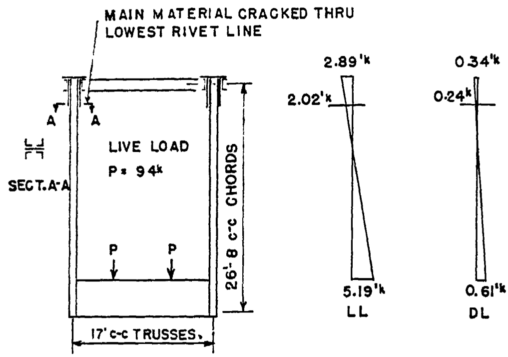


FIG. 5
TYPICAL FAILURE SECTION
DECK RIVETED TRUSS SPANS
9 FAILURES IN THREE SPANS



SKETCH MOMENTS

RANGE OF STRESS - AXIAL + BENDING ksi

	FAILURE SECT. A-A		TOP FLOOR BEAM
	GROSS AREA	NET AREA	GROSS AREA
MAX. D+L+64.7% I	14.4	19.5	16.0
MIN. D	1.2	1.6	1.2

GENERAL DATA

SPAN - 120'-0 T.R.T.
BUILT - 1902
HANGER FAILURE - 1941 OR EARLIER
NO. OF FAILURES - 22 IN 15 IDENTICAL SPANS
ESTIMATED NO CYCLES CAUSING ABOVE LL STRESS - UNKNOWN

SECTION
4 L^s 4 × 3 × $\frac{3}{8}$
1 PL 9 × $\frac{5}{16}$

REFERENCE: FIGS. 6, 14

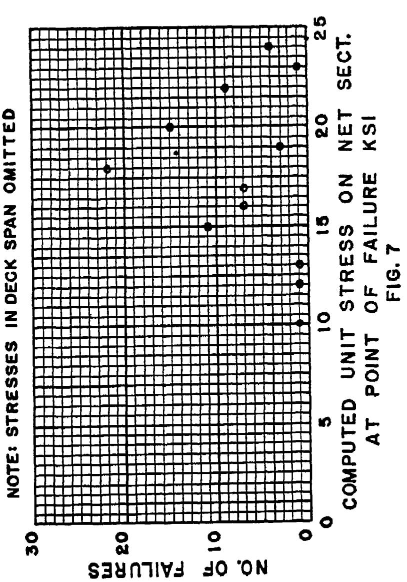
FIG. 3
SUMMARY DATA
STRESS ANALYSIS OF FLOOR BEAM HANGER
120'-0 THRU RIVETED TRUSS

The stress analysis of these failures was made by N. Y. Lu and A. A. Thorup, research associates, assisted by Messrs. W. R. Bayles, H. C. Brewer, L. M. Caryl, J. C. Isnard, R. I. Kaufman, I. A. Mohammed, and A. T. Shak, research assistants.

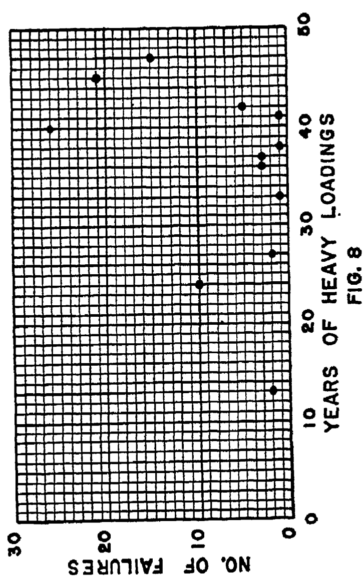
3. Analysis of the Failures and Conclusions

The bending stresses in the hangers due to floorbeam deflection were computed by a modification of the slope deflection method which takes into account the effect of the depth of the floorbeam and the hangers.[1] Successive approximations were used in solving the equations. Owing to the uncertainties existing at the present time regarding the effect of differential truss settlement upon stress distribution, particularly where portal bracing is involved, no computations were made of this effect in the skew spans. In the case of the 160-ft. through skew span, however, measured stresses due to LL + I were obtained by the AAR research office, and these are used in Table 1. Where no plans

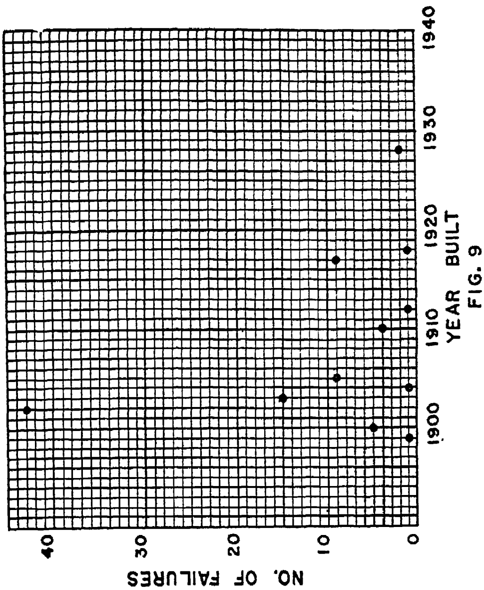
[1] AREA Bulletin 454, 1945. Two Problems in Bridge Design, by L. T. Wyly.



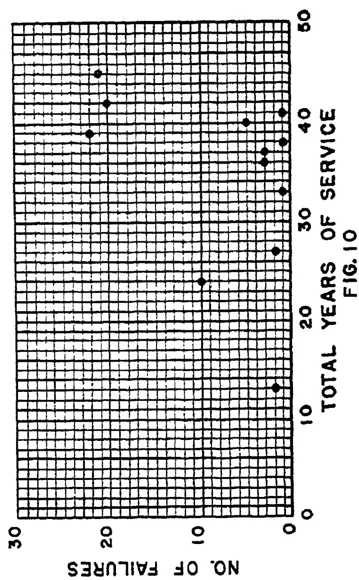
COMPUTED UNIT STRESS ON NET SECT.
AT POINT OF FAILURE KSI
FIG. 7



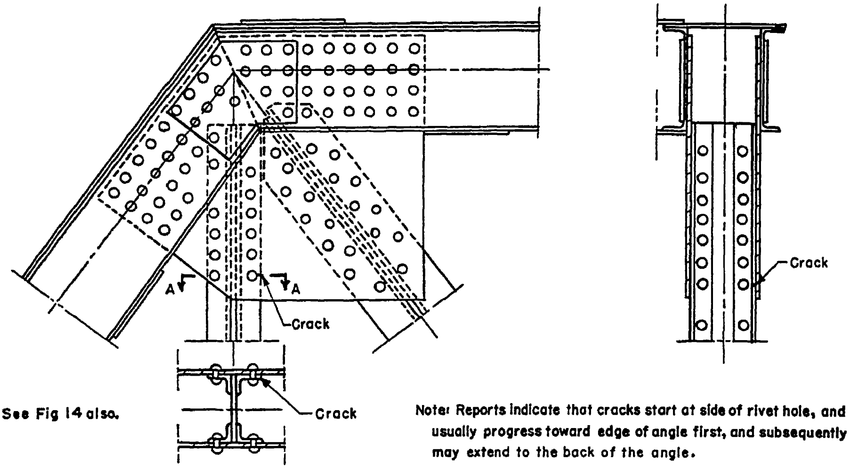
YEARS OF HEAVY LOADINGS
FIG. 8



YEAR BUILT
FIG. 9



TOTAL YEARS OF SERVICE
FIG. 10



See Fig 14 also.

SECTION A-A

Note: The cracks start in any one of the four angles of the hanger.

Note: Reports indicate that cracks start at side of rivet hole, and usually progress toward edge of angle first, and subsequently may extend to the back of the angle.

FIG. 6
TYPICAL FAILURE SECTION
120'-0 RIVETED THRU TRUSS SPAN
22 FAILURES IN 15 IDENTICAL SPANS

were furnished by the reporting railroad, only axial stresses in the hanger are shown and are so marked.

The analysis of the 91 failures in 51 different spans in 22 bridges owned by 7 different railroads, shown in Tables 1, 2, 3, and Figs. 1 to 16, incl., reveals the following facts:

(a) Of these failures, 12 occur in the hanger adjacent to the floorbeam, and 9 of these 12 occur in a deck bridge where the computed unit stresses on the net section exceed the elastic limit of the material when rigid frame bending is taken into account. See Table 1 and Figs. 1, 2, 4, 5, 11, 12 and 13.

(b) The remaining 79 failures have occurred in the main material of the hanger at the lowest line of rivets connecting the hanger to the upper chord gusset. See Table 1 and Figs. 3, 6, 14, 15 and 16.

(c) These 79 failures do not occur at the point of largest computed stress. See Fig. 3.

(d) The failures occur after an estimated relatively small number of loadings producing computed unit stresses of no very great magnitude. See Table 1 and Figs. 3, 6, 7, 14, 15 and 16.

(e) The range of stress caused by the addition of live load plus impact is relatively large since the dead load stress carried by these hangers is generally under 2 ksi. See Table 1 and Figs. 11 to 16, incl.

(f) The failures at the top chord gussets may occur at either the inside or outside gusset and on either side of the member.

(g) No evidence of corrosion or injury to the metal has been reported.

(h) The failures are by brittle and progressive fracture and evidently fatigue failures.

(i) There does not appear to be any correlation of failure with temperature.
(j) The gussets do not fail.
(k) The gussets are usually, but not always, thicker than the hanger material.
(l) The holes through which the failures occur are always close to the edge of the leg of the angle.
(m) There are usually holes in the other angle leg or the channel flange close to the holes through which the cracks pass.
(n) The reports indicate that the failure crack starts at the side of the rivet hole nearest the edge of the angle and progresses first to the edge of the angle and afterwards to the back of the angle, and even through the other leg.
(o) In practically all cases there is a fill or gusset or other reinforcing plate on the track side of the hanger which extends up above the floorbeam or floorbeam bracket. This was not true in the case of the 114-ft. 8¼-in. span, however. See Fig. 4.
(p) In most cases, the computed unit stress on the net section apparently producing failure was from 18 to 22 ksi. The maximum unit stress computed for any of these members was 24 ksi. and the minimum was about 10 ksi. See Table 1 and Fig. 7.
(q) The average estimated number of repetitions of heavy loadings of the hanger was about 40,000 or less. The maximum estimated number of repetitions of heavy loadings is 180,000 and the minimum estimated number is about 20,000.
(r) The largest number of structures showing these failures was built in 1902. The earliest year of construction reported was 1899 and the latest was 1928. See Fig. 9.
(s) The average number of years of service under heavy loading preceding failure was 36 to 45. The largest number of years was 47 and the minimum number was 13 years. See Fig. 8.
(t) In all cases, the rivets connecting the hanger to both upper and lower chord gussets are in single shear.
(u) In the deck bridge noted in (a) above, there were two spans each of which developed four failures. See Table 1.
(v) In the skew bridges, there were three spans each of which developed three failures, and five spans each of which developed two failures.
(w) In the deck bridge the computed direct stress plus bending due to floorbeam deflection in the hanger is well above the elastic limit of the material by any reasonable assumptions. See Figs. 12 and 13. It is highly significant that while the nine failures in the hangers of this bridge occurred at the point of greatest computed stress, they also occurred at the holes for the lowest line of rivets connecting the hanger to the U_1 gusset.

II. Report on Failures in Pin-Connected Truss Spans

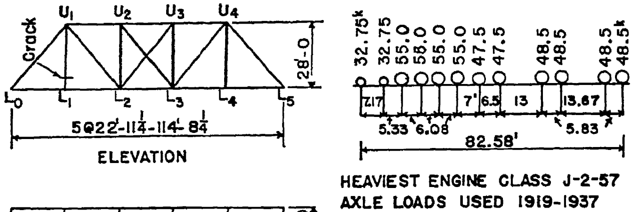
1. Digest

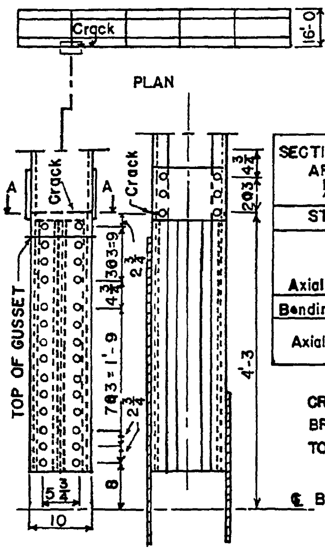
This report comprises a summary of all the information submitted by various railroads concerning failures in the floorbeam hangers of pin-connected truss spans; a stress analysis; a classification of failures according to location.

A list of all the types of failures and the calculated unit stresses in the hangers is shown in Table 4. Typical details of the hanger indicating location of failures and other pertinent data for each type of failure are given in Figs. 17 to 21, incl.

The outstanding facts brought out by this report are:

(text continued on page 494)





SECTION A-A		GROSS		NET	
AREA		11.76 in²		9.61 in²	
I/c		60.80 in³		52.30 in³	
STRESS ON FAILURE SECTION A-A					
	D.L.	L.L.	I 65.7%	TOTAL	Unit Stress Net Section
Axial	17.25	98.4	64.5	180.15k	18.75 ksi
Bending	1.49	11.04	7.3	19.83 'k	±4.56 ksi
Axial plus Bending			Inside Angle		23.31 ksi
			Outside Angle		14.19 ksi

CRACK LOCATED TOWARDS ℄ OF BRIDGE, LOCATION WITH RESPECT TO END OF BRIDGE NOT KNOWN.

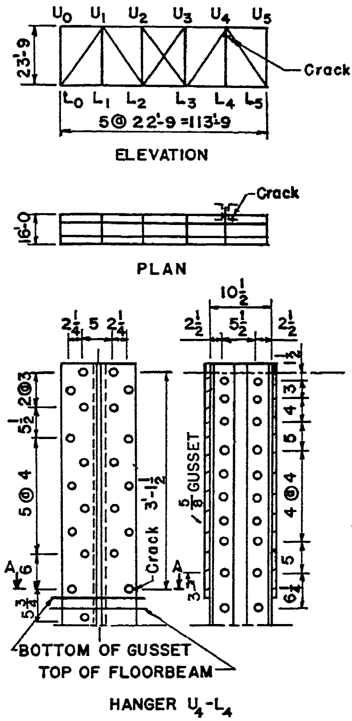
℄ BOTTOM CHORD

BRIDGE BUILT	1910
FAILURES FOUND	1937
NO. OF FAILURES	1

HANGER $U_1 L_1$
2[10 X 20#
LACED

RIVETS $\frac{7}{8}$ DIA.
MATERIAL: MEDIUM STEEL

FIG. 11
114'-8¼ THRU RIVETED TRUSS
ONE TRACK



SEE FIG. 12

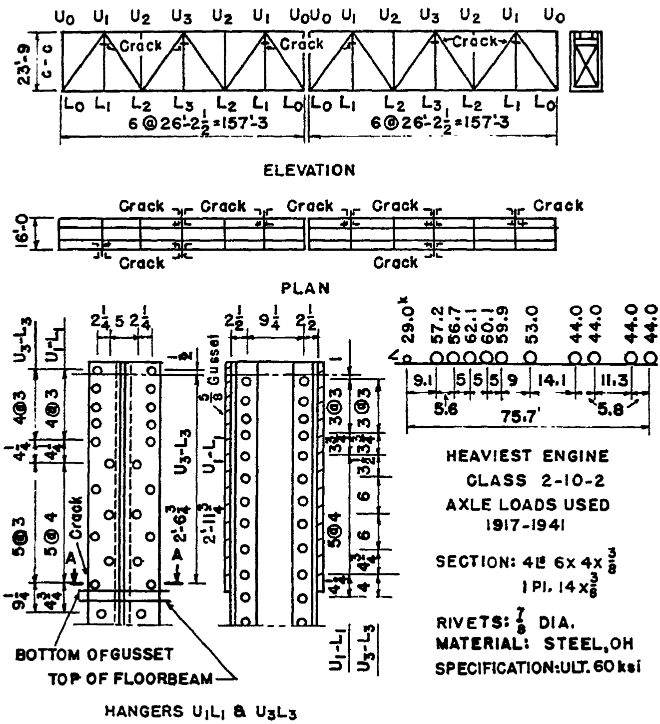
SECTION: 4 Ls 6 x 4 x $\frac{3}{8}$
1 Pl. 10 x $\frac{3}{8}$

RIVETS: $\frac{7}{8}$ DIA.
MATERIAL: STRUCTURAL O.H. STEEL

SECTION A-A			GROSS		NET
AREA			18.19 In²		16.60 In²
I/c			60.7 In³		53.0 In³
STRESS ON FAILURE SECTION A-A					
	D.L.	L.L.	I. 65.3%	TOTAL	Unit Stress Net Sect.
Axial	13.2	116.0	75.8	205.0^k	12.35 ksi
Bending	12.3	108.0	70.5	190.8'^{k}	43.25 ksi
Axial Plus Bending			Outside Angle		-30.9 ksi
			Inside Angle		55.6 ksi

BRIDGE BUILT 1917
FAILURES FOUND 1941
NO. OF FAILURES 1

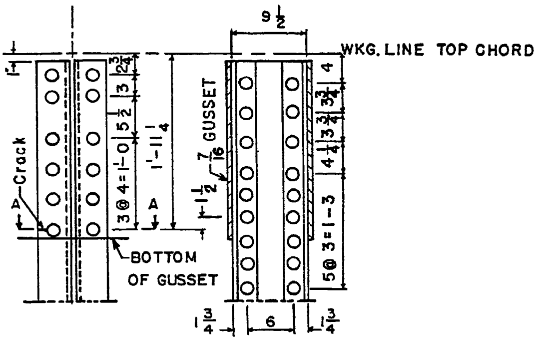
FIG. 13
113'-9 DECK RIVETED TRUSS SPAN ONE TRACK



SECTION A-A		GROSS		NET	
AREA		19.69 in²		16.03 in²	
I/c		92.2 in³		75.6 in³	
STRESS ON FAILURE SECTION A-A					
	D.L.	L.L.	I. 64.9%	TOTAL	Unit Stress Net Sect.
Axial	15.1	124.5	80.8	220.4k	13.75 ksi
Bending	17.6	145.4	94.5	257.5'k	40.85 ksi
Axial Plus Bending			Outside Angle		-27.1 ksi
			Inside Angle		+54.6 ksi

SEE FIG. 13 ALSO

FIG. 12
157'-3 DECK RIVETED TRUSS SPANS ONE TRACK

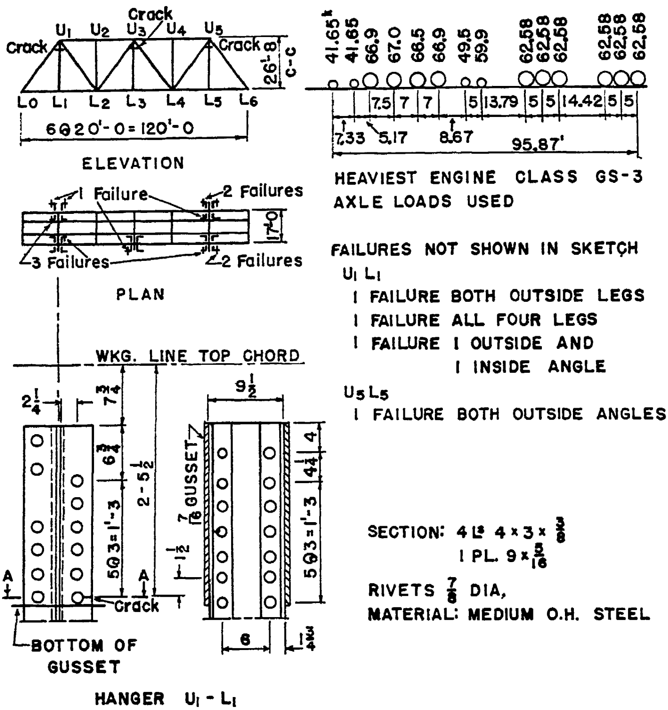


HANGER U_3-L_3
4 L 4 x 3 x $\frac{3}{8}$
1 PL. 9 x $\frac{5}{16}$

SECTION A-A	GROSS			NET	
AREA	12.73 in^2			9.43 in^2	
$\frac{I}{c}$	38.5 in^3			28.5 in^3	
STRESS ON FAILURE SECTION A-A					
	DL	LL	I 64.7%	Total	Unit Stress Net Section
Axial	15.81	94.0	60.8	170.6^K	18.10 ksi
Bending	0.06	0.53	0.34	0.93	0.40 ksi
Axial Plus Bending			Outside Angle Inside Angle		18.50 ksi 17.70 ksi

See Figure 14

FIG. 15
120'-0 THRU RIVETED TRUSS
ONE TRACK

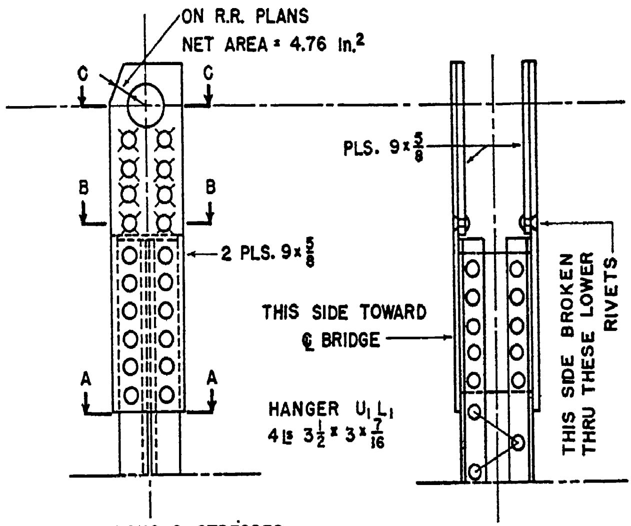


SEE FIG. 15 ALSO

SECTION A-A			GROSS		NET
AREA			12.73 in^2		9.43 in^2
I/c			38.5 in^3		28.5 in^3
STRESS ON FAILURE SECTION A-A					
	D.L.	L.L.	I 64.7%	TOTAL	Unit Stress Net Sect.
Axial	14.72	94.0	60.8	169.5 k	17.97 ksi
Bending	.24	2.02	1.31	3.57'k	1.50 ksi
Axial Plus Bending			Outside Angle		19.47 ksi
			Inside Angle		16.47 ksi

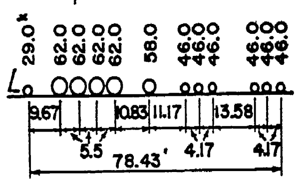
SPANS FABRICATED 1902
FAILED 1941
22 HANGER FAILURES IN
15 IDENTICAL SPANS

FIG. 14
120'-0 THRU
RIVETED TRUSS



SECTIONS & STRESSES

AREAS IN SQUARE INCHES			
SECTION	A-A	B-B	C-C
GROSS	10.60	11.25	22.50
NET	8.20	8.37	10.60
UNIT STRESSES IN ksi			
ON NET SECTION	17.0	16.7	13.2



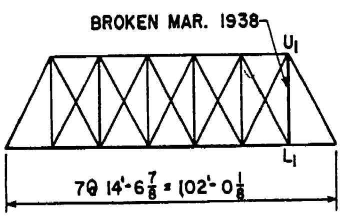
LOCOM. CLASS H-10 AXLE LOADS

MATERIAL
RIVETS: $\frac{3}{4}$ DIA.
BRIDGE BUILT IN 1901
BROKEN MAR. 1938
NO. OF FAILURES 1

STRESS IN $U_1 L_1$

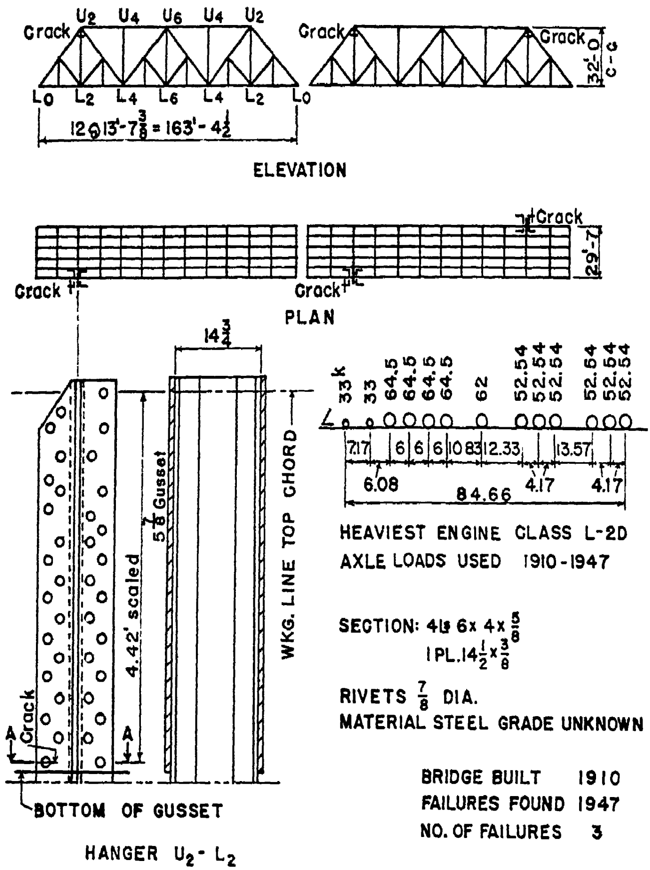
D.L. (FROM PLANS)	= 10.8^k
L.L. (LOCOM. CLASS H-10)	= 77.3
* IMP. (66.1 %)	= 51.1
TOTAL	= 139.2^k

* ASSUMED TRUSS SPACING = 15'-6



ELEVATION

FIG. 17
102'-0$\frac{1}{8}$ P.C. THRU TRUSS SPAN
ONE TRACK



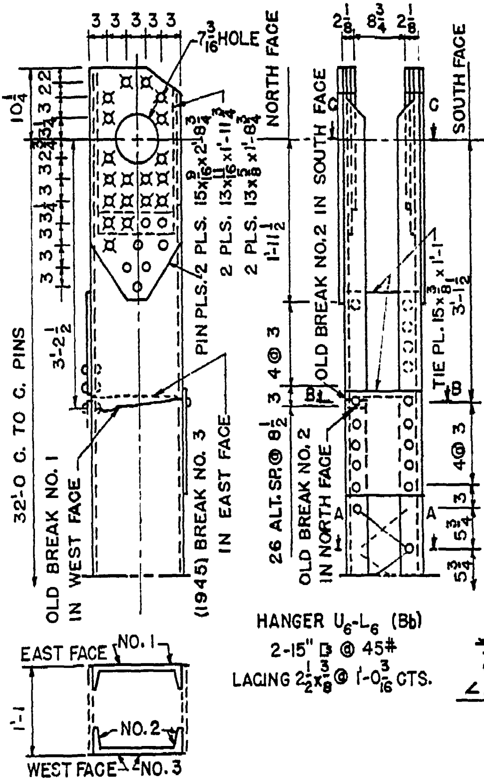
SECTION A-A	GROSS	NET
AREA	28.88 in^2	23.15 in^2
I/C	145.6 in^3	117.5 in^3

STRESS ON FAILURE SECTION A-A

	D.L.	L.L.	I. 66.1%	TOTAL	Unit Stress Net Sect.
Axial	59.0	175.5	116.0	350.5^k	15.15 ksi
Bending	2.14	12.52	8.28	22.94$'^k$	2.34 ksi
Axial Plus Bending			Outside Angle		17.49 ksi
			Inside Angle		12.81 ksi

Note: Stresses given are for one track loaded

FIG. 16
163'-4½ THRU RIVETED TRUSS
TWO TRACKS



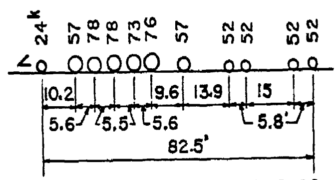
STRESS IN U_6-L_6

D.L. FROM PLANS	=	33^k
L.L. (LOCOM. N-1s)	=	249*
IMPACT (62.6%)	=	156
TOTAL	=	438^k

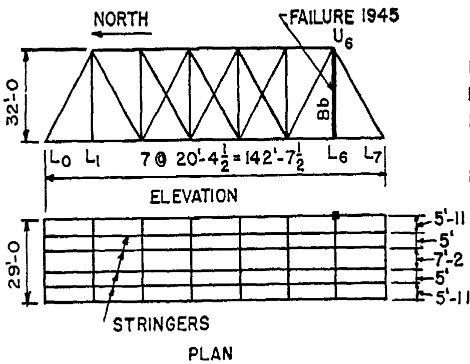
*BOTH TRACKS LOADED

SECTIONS AND STRESSES

AREAS IN SQUARE INCHES			
SECTION	A-A	B-B	C-C
GROSS	26.34	26.34	77.46
NET	25.09	23.84	41.66
UNIT STRESSES IN ksi			
ON NET SECTION	17.5	18.4	10.5



LOCOM. CLASS N-1s - AXLE LOADS



MATERIAL: SOFT STEEL
RIVETS: $\frac{7}{8}$ DIA.
BRIDGE BUILT IN 1901
FAILURE OCCURED IN 1945
NUMBER OF FAILURES 1

FIG. 19
$142'\text{-}7\frac{1}{2}$ P.C. THRU TRUSS SPAN
TWO TRACKS

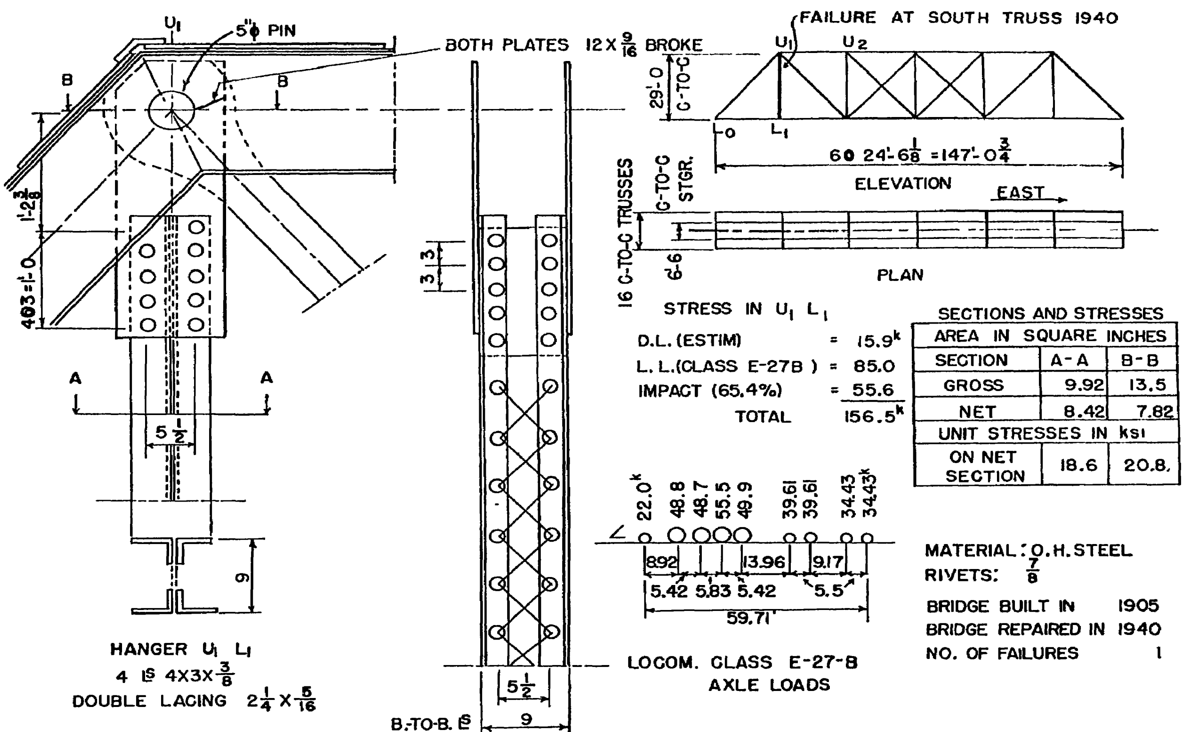
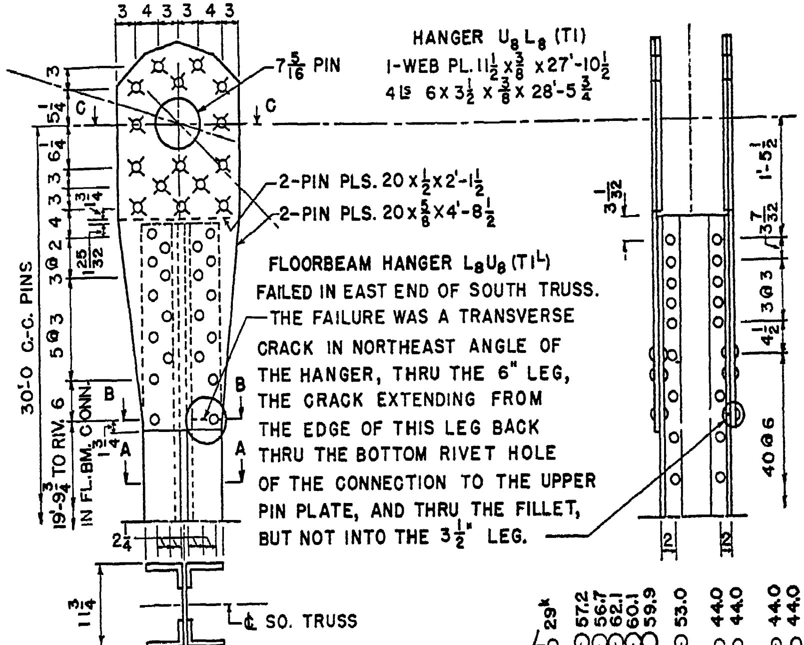


FIG. 18
147'-0 3/4 P.C. THRU TRUSS SPAN
ONE TRACK

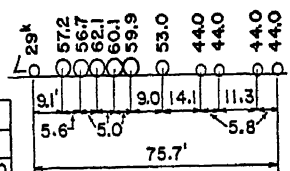


STRESS IN U_8L_8

D.L. (FROM PLANS) = 31.70^k
L.L. (SANTA FE LOC.) = 134.00
IMPACT (64.0%) = 85.80
TOTAL = 251.50^k

SECTIONS AND STRESSES

AREAS IN SQUARE INCHES			
SECTION	A-A	B-B	C-C
GROSS	17.99	17.99	45.00
NET	15.74	15.09	22.36
UNIT STRESSES IN ksi			
ON NET SECTION	16.0	16.7	11.3



SANTA FE TYPE - AXLE LOADS

MATERIAL: MEDIUM STEEL
RIVETS: $\frac{7}{8}$ DIA.
BRIDGE BUILT IN 1905
FAILURE NOTED IN 1948
NUMBER OF FAILURES 1
PRIOR TO FAILURE ESTIMATED AVERAGE DAILY NUMBER OF TRAINS WAS ABT. 20 OF WHICH ABT. 10 WERE HAULED BY SANTA FE TYPE LOCOMOTIVE.

FAILURE IN 1 HANGER-(1948)

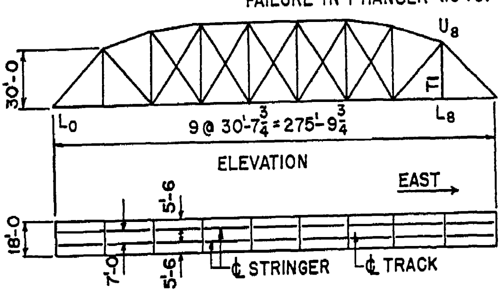
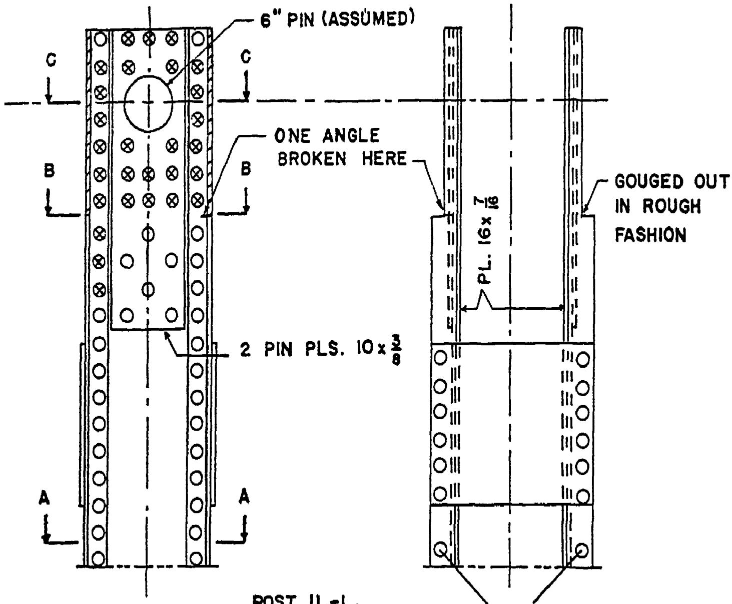


FIG. 21
$275'-9\frac{3}{4}$ P.C. THRU TRUSS SPAN
ONE TRACK



POST U_6-L_6
4 Ls 3x3x$\frac{3}{8}$
2 WEB PLS. 16 x $\frac{7}{16}$

STRESS IN U_6-L_6

D.L. (FROM PLANS)	= 16.0^k
L.L. (FROM PLANS, E 55)	= 165.5 †
* IMP. (65.0%)	= 107.8^k
TOTAL	= 289.3^k

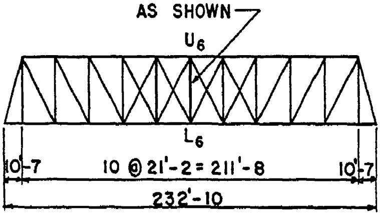
* ASSUMED TRUSS SPACING = 17'-0

† BOTH TRACKS LOADED

SECTION AND STRESSES

AREA IN SQUARE INCHES			
SECTION	A-A	B-B	C-C
GROSS	22.44	29.94	27.50
NET	17.97	27.50	17.80
UNIT STRESS IN ksi			
ON NET SECTION	16.1	10.5	16.2

NOTE: AT LEAST 5 POSTS FAILED AS SHOWN



ELEVATION OF CENTER TRUSS

MATERIAL:
RIVETS: $\frac{7}{8}$ DIA.
BRIDGE BUILT IN 1898
FAILURES IN 1937
NO. OF FAILURES 5

FIG. 20
232'-10 P.C. THRU TRUSS SPAN
TWO TRACKS

TABLE 4 LIST OF PIN CONNECTED TRUSS SPANS WITH FAILURES IN FLOOR BEAM HANGERS

FIG. NO.	NO. SPANS	SPAN LENGTH	TRUSS TYPE	NO. OF TRKS	YEAR BUILT	YEAR FAILED	NO. OF FAILURES	FLOOR BEAM HANGER SECTION	POINT OF FAILURE	UNIT STRESS ON NET SECTION - ksi: NO. TRACKS LOADED	MAIN MATERIAL	AT POINT OF FAILURE	AT PIN HOLE	
17	1	102'-0⅛	THRU	1	1901	1938	1	4∠s 3½X3X7/16 LACED	PIN PLATE	1	17.0	16.7	13.2	
	1	139'-2	THRU SKEW	3	1896	1933	1	4∠s 5X3X3/8, 1Pl.12X5/16		1	12.0	13.0	14.1	
						1933	2	" "		1	11.6	13.6	13.6	
						1936	1	4∠s 5X3X3/8, Pl 12X3/8		2	18.9	15.6	15.6	
18	1	147'-0¾	THRU	1	1905	1940	1	4∠s 4X3X7/8 LACED		1	18.6	20.8	20.8	
	1	160' ABT	DECK	1	1895	1945	2	4∠s 3½X3X3/8, 1Pl.7¼X7/16	PIN PLATES	1	—	24.9	24.9	
	1	146'-3	THRU	1	1880 & 1903	1942	1	2Pl. 10X½		1	11.5	—	14.2	BEARING ON PIN 26.2
	1	232'-6				1942	2	2Pl. 10X½			11.5	—	15.1	" " " 23.7
	1	232'-10	"	1	1898	1930	1	4∠s 4X3X½		1	19.4	20.2	20.2	
19	1	142'-7½	"	2	1901	1945	1	2-15" [s @ 45# LACED		2	17.5	18.4	10.5	
	1	149'-11	"	2	1901	1945	1	2-15" [s @ 45# LACED	STAY PLS.	2	18.1	18.5	9.5	
	1	169'-0	"	1	1899	1925	1	2-10" [s @ 51#/YD. LACED		1	17.7	19.1	13.6	
	1	177'-6	"	1	1894	1937	1	2-10" [s @ 21# LACED		1	18.3	19.9	11.4	
							1	" "			18.3	20.3	11.4	
	1	126'-0	"	1	1900	1945	1	2-12" [s @ 30# LACED		1	11.5	12.0	10.4	
	1	132'-8	"	1	1900	1945	4	2-12" [s @ 30# LACED		1	11.9	12.5	11.6	
	1	154'-0	"	1	1902	1945	1	4∠s 3½X3½X7/16, 2Pl.15X½ LACED		1	11.1	11.1	8.8	
							3	" " " "			11.1	13.4	8.8	
	3	160'-6	DECK	2	1901	1937	14	4∠s 3X3X½, 2Pl.12X5/8 LACED		2	17.6	20.9	20.9	STRESSES ON GROSS SECT.
20	1	232'-10	THRU	2	1898	1937	5	4∠s 3X3X3/8, 2Pl.16X7/16 LACED		2	16.1	10.5	16.2	
	1	248'-6	"	2	1903	1945	4	4∠s 4X4X½, 2Pl.24X½ LACED	COPED FLANGES	2	17.7	10.3	9.4	
	17	255'-0	DECK	1	1904	1947	10	4∠s 4X4X½, 2Pl.20X½ LACED		1	6.5	—	—	STRESS ON GROSS SECTION
	1	273'-0	THRU	2	1895	1945	1	4∠s 4X3½X3/8, 2Pl.22X7/16 LACED		2	16.6	13.3	9.4	
							3	" " "			16.6	7.7	9.4	
	1	373'-1	"	2	1904	1945	2	4∠s 4X4X½, 2Pl.24X5/8 LACED		2	14.9	6.4	9.3	
	1	387'-10	"	1	1902	1945	1	4∠s 3½X3½X3/8 2Pl.20X7/16 LACED		1	11.9	11.9	6.8	
							2	" " "			11.9	11.8	6.8	
							1	" " "			11.9	6.3	6.8	
	1	407'-0	"	2	1902	1945	1	4∠s 4X4X½, 2Pl.24X5/8 LACED		2	15.4	15.8	9.8	
							1	" " "			15.4	6.8	9.8	
	1	94'-0	"	1	1902	1938	1	4∠s 3½X3X7/16 LACED		1	13.3	16.7	8.1	
	1	142'-6¾	THRU SKEW	1	1903	1941	1	4∠s 5X3½X3/8 1Pl.8X3/8		1	17.9	18.8	12.0	
	1	147'-7½	THRU	1	1903	1941	1	4∠s 5X3½X3/8, 1Pl.7X3/8		1	17.2	19.2	12.4	
								" "	LOWEST RIVET LINE			8.7		
	1	150'-9	THRU	1	1903	1945	1	4∠s 6X3½X3/8, 1Pl.7½X3/8		1	12.7	13.4	13.3	
	1	155'-3	THRU SKEW	1	1905	1945	1	4∠s 5X3½X3/8, 1Pl.7X3/8		1	13.7*	13.7*	11.7	*ON GROSS SECTION
	1	232'-10⅝	THRU	2	1901	1948	1	4∠s 6X4X9/16 LACED		1	9.7	10.3	7.1	
							1	" "		2	16.2	17.2	8.0	
21	1	275'-9¾	"	1	1905	1948	1	4∠s 6X3½X3/8 1Pl.11½X3/8		1	16.0	16.7	11.3	

A

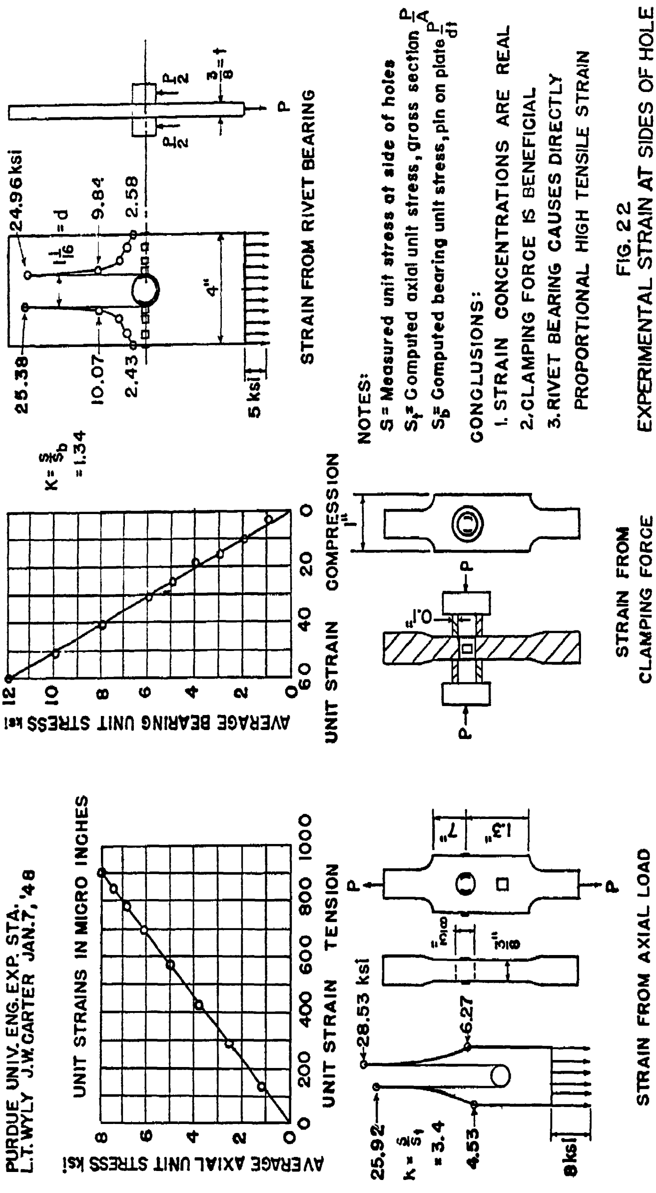


FIG. 22
EXPERIMENTAL STRAIN AT SIDES OF HOLE

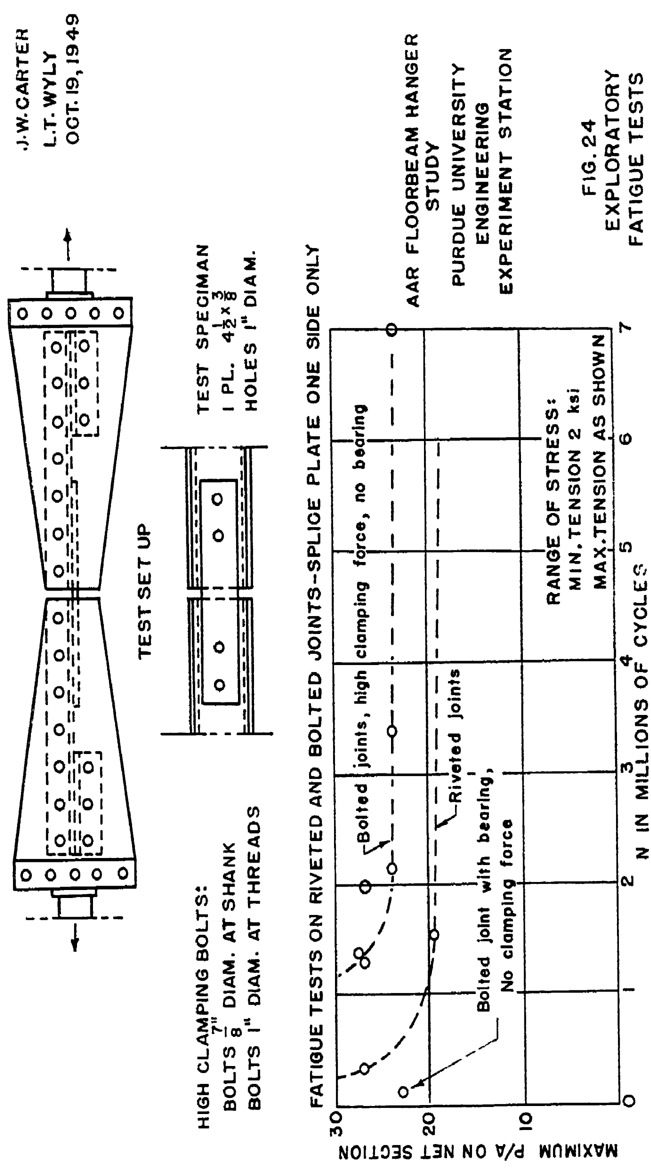


FIG. 24
EXPLORATORY
FATIGUE TESTS

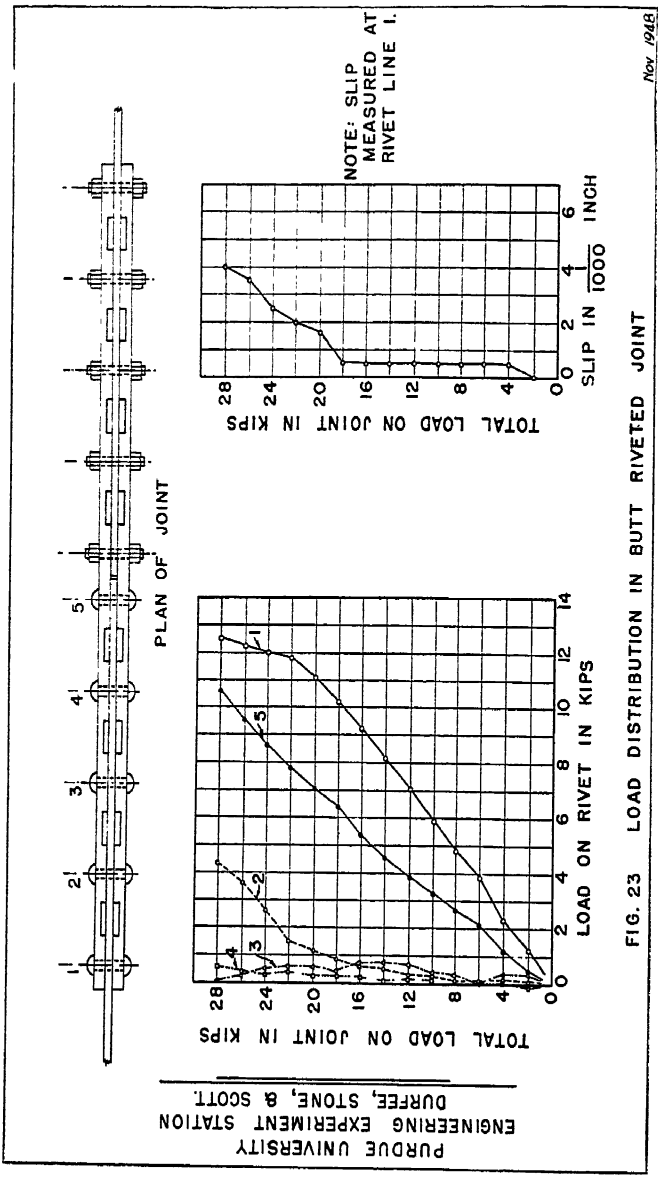


FIG. 23 LOAD DISTRIBUTION IN BUTT RIVETED JOINT

(e) Five failures occurred close to the top of a post of a through span where the calculated compressive axial unit stress was 10,500 psi. The bending stresses at the point of failure in this post should have been very small unless the load was carried entirely by the one prong of the forked end member. See Fig. 20.

4. Probable Causes of the Failures

The explanation for these failures in the hangers of the pin-connected spans at low unit stresses lies undoubtedly in the use of the forked ends with the two prongs bearing on the pin. Any imperfection of bearing of either prong on the pin will set up a severe local bending or racking in the member where the forked ends join the stiffly braced section of the member. It should be noted that in many cases bending of the forked end may be considerable due to local eccentricities. Such eccentricities arise from the addition of splice plates, coping of flanges and uneven wear, which shift the center of bearing on the pin.

The effect of the addition to a forked end condition of such a severe stress raiser as a cope results in the superimposing of high local stress concentrations upon the bending stress in the forked end. It is notable that in only one or two cases were copes present in the members without the failure crack passing through the re-entrant angle of the cope.

5. Conclusions

(a) The occurrence of a large number of fatigue failures in members having such large stress raisers as forked ends and coped flanges tends to substantiate the theory of the relation between maximum stress or strain and fatigue strength, and shows how failure will result in such members under a considerable number of repetitions of low axial stresses.

(b) It is noteworthy that the axial unit stresses producing failure in the hangers of the pin-connected spans are about 4 ksi. to 6 ksi. lower than the axial unit stresses which produced failures in the riveted spans. This lower fatigue strength may be directly attributed to the presence of the large stress raisers in the pin-connected hangers. It is also especially notable that the more severe the stress raiser the lower the fatigue strength.

(c) It appears probable that many of the floorbeam hangers of pin-connected trusses now in service having stress raisers similar to those shown in this report will fail as soon as the number of repetitions of stresses becomes large enough.

(d) The failures here reported fall into certain definite location categories, all of which are characterized by high local stress concentrations. The location of these failures can be used as a guide for field inspection of hangers now in service.

III. Laboratory Investigation

1. Digest

This report lists the causes which, in the opinion of the committee, contribute to the failures, summarizes the results of exploratory laboratory tests made in an attempt to explain the failures, offers a working hypothesis for causes and remedy of the failures, lists some of the unsolved problems and outlines the laboratory studies under way at Purdue.

Figs. 22, 23 and 24 give the results of the exploratory laboratory tests. Fig. 25 shows a view of a scale model of a floorbeam and hanger rigid frame being tested in the laboratory at Purdue.

(text continued from page 479)

(a) Railroad bridge members, such as floorbeam hangers, subjected to a large number of repetitions of stress, will fail at calculated axial stresses as low as 6300 psi.

(b) More failures occur in floorbeam hangers having the outstanding legs of angles or channels coped to clear other truss members than in any other type of hanger.

2. Foreword

On June 30, 1949, Mr. Magee sent to the chief engineers of member railroads a report on the failures in pin-connected spans, together with 25 additional figures showing details for each hanger failure so far reported. Additional copies of this report are available upon request to the research engineer, AAR.

The information in Table 4 was assembled and analyzed by Professor Wyly and Mr. Thorup. The figures and stress computations were made by A. A. Sirel*.

3. Analysis of the Failures

The analysis of the 79 failures in 28 different pin-connected bridges indicates that these failures can be classified into the following definite location categories:

(a) Two hangers failed through the pin plates at the top of the main material where the pin plate joins the hanger, as shown in Fig. 17.

(b) Ten hangers failed in the pin plate through the pin hole. See Fig. 18.

(c) Five hangers failed in the main material through the end rivet in the stay plates. See Fig. 19.

(d) Fifty-four hangers failed through the re-entrant angles at the copes of flanges. See Fig. 20.

(e) Eight hangers failed in the main material through the lowest line of rivets connecting the main material to the pin plates. See Fig. 21.

The calculated maximum axial unit stress on the net section under the heaviest locomotives operating over the bridge is shown in Table 4. The computed stresses are based upon dead load, live load and impact in accordance with 1949 AREA Specifications for Steel Railway Bridges. The bending stresses in the hangers resulting from the stringer and floorbeam deflections were not computed since most of the failures occurred on a section close to the top of the hanger where the calculated bending stresses are negligible for a pin-connected span.

The calculated maximum axial unit stress on the net section is considerably lower than the usual design stress for bridge members, and failure undoubtedly resulted from a large number of cycles of these low stresses at sections having large stress raisers such as that produced by the re-entrant angle at the copes of the flanges, see Fig. 20. The following data regarding the calculated stresses are outstanding:

(a) There were 17 failures where the calculated stress in the hanger was below 10,000 psi.

(b) Twenty-five hangers failed where the calculated tensile stress was between 10,000 and 15,000 psi.

(c) There were 18 failures where the calculated tensile stress in the hanger was over 15,000 psi.

(d) Fourteen failures occurred close to the top of a post of a deck span where the calculated compressive axial stress was 20,900 psi., however, these posts were undoubtedly subjected to large bending stresses resulting from the stringer and floorbeam deflection. See Fig. 19.

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* Assistant structural engineer, AAR research staff.

It seems obvious that the shortening of the fibers at the sides of the hole due to this action will vary with different ratios of hole diameter to plate width and thickness, as well as with magnitude of clamping force. Also in the connection of the hanger, the loading conditions would vary from the above, since one side of the hanger would bear against a flat plate (the gusset) instead of against the rivet head. Again, bending may be set up in the plate in case the two surfaces do not fit perfectly. It is also evident that the frictional forces developed as a result of this clamping will have an important effect upon the distribution of load and stress in the riveted joint. This may well be the most important result of the clamping force so far as the stress concentrations at the sides of the holes are concerned.

3. Stress Concentrations at Sides of the Hole Caused by Rivet Bearing on Main Material at Top of Hole

The stress concentrations at the sides of the hole due to the rivet bearing on the main material at the top of the hole is illustrated at the right of Fig. 22 (c). The stress concentration due to this condition is seen to be five times as great as the average stress on the gross section.

If the allowable bearing stress of 27 ksi. is used at the top of the hole as is commonly done, the resultant equivalent elastic stress at the sides of the hole, due to this bearing alone, will be about 35 ksi., and the actual strain increment will correspond to the strain produced elastically by a stress of 35 ksi., as long as the elastic limit of the material at the sides of the hole is not exceeded. If this elastic limit is exceeded, the strains will be even greater. Note that this is to be added to the strains due to the presence of the hole discussed above. Furthermore, since the connection of the hanger to the gusset puts the rivets in single shear, any slip of the hanger relative to the gusset will cause the rivet to twist in a vertical plane and bear still more heavily at the top of the hole on the outside surface of the hanger. This increase of bearing locally may be quite severe and will cause a corresponding increase in the strain at the sides of the hole at the face of the member. The magnitude of this strain will depend upon the clamping force in the rivet shank, the amount of the slip, the grip, etc.

It is generally conceded, thanks to the work of Professor W. M. Wilson and others, that hot driven rivets probably do not completely fill the holes, even for short grips. Since the hanger will carry nearly full load, and hence stretch elastically, above the lowest line of rivets in the upper chord gusset, while the gusset will carry little load in this point, and hence will stretch very little, it seems highly probable that there will be a slip of the hanger relative to the gusset at this point, and that in many cases these lowest rivets may come to bear on the hanger and gusset material.

To secure some index of this action a test of a simple riveted joint having a single line of rivets was made at Purdue. The results are illustrated in Fig. 23. The main plates were 2½ by ½ in. The rivets were ⅝ in. dia. Each splice plate was 2½ by ¾ in. These were cut to a thickness of ⅜ in. between rivets to permit the placing of SR–4 gages on the main plates. Based on present allowable unit stresses the design load for the five rivets would be about 41 kips for shear, about 46 kips for bearing, and the design load for the plate would be 33 kips. The following facts are illustrated by Fig. 23:

(a) Slip of the splice plates with respect to the main plates began at about 50 percent of the design load of 33 kips and had reached the amount of 0.004 in. at a 28-kip load.

(b) The end rivets, Nos. 1 and 5, carried almost all the load so far as this test was carried. No. 2 began to come into effective action in a minor way at a load of 22 kips. The other rivets carried almost no load in this test.

2. Foreword

The measurements of load and slip distribution in a single line riveted joint were made by J. M. Durfee and R. M. Stone, graduate students, under the direction of M. B. Scott*. The laboratory studies in static and fatigue testing were performed by J. W. Carter** under the direction of Professor Wyly. The fatigue testing machine was operated by E. C. Thoma***. The rigid frame model was designed and is being tested by J. W. Cox.**

3. Probable Causes of the Failures

The influence of local stress concentrations in reducing the fatigue strength of a member is well established. Consequently, the above facts point directly toward large local stress concentrations in the main material at the sides of the holes for the lowest line of connecting rivets in the upper chord gussets. Investigation of the circumstances likely to produce such stress concentrations at these points should include the following:

1. The effect of the rivet hole itself.
2. The effect of the clamping action of the hot-driven rivet on the material around the hole.
3. The effect of the bearing of the rivet on the stress at the sides of the hole.
4. The effect of impact loads upon stress concentrations at the rivet holes.

The results of some simple pilot or exploratory laboratory tests made at Purdue to investigate the relative magnitude of stress concentrations due to the first three above causes are shown in Figs. 22 to 24, incl. Stresses were measured with SR–4 wire gages. The plates were mild steel.

1. Stress Concentration Caused by a Hole in a Flat Plate under Uniform Axial Tension

The stress concentration due to the presence of a hole centrally located is illustrated in Fig. 22 (a). With a unit stress of 8 ksi. on the gross section of the bar shown, a local stress at the side of the hole would average about 27 ksi., or 3.4 times as large.

Previous photoelastic studies have shown that the exact value of this stress concentration depends upon the size of the hole compared to the width of the plate and also upon the position of the hole in the plate. Measurements under static locomotive loadings taken at the sides of open rivet holes in the hangers of the bridge of the Missouri–Kansas–Texas Lines at Erie, Kans., in 1948, show that strain concentrations are realized in full-sized members in service. Also the effect of other adjacent holes or stress raisers upon the stress at the sides of the given hole is to be considered.

2. Effect of Clamping Force of Rivet upon Metal at the Sides of Rivet Holes

The strain concentrations at the sides of a hole due to the clamping action of the hot driven rivet are illustrated by Fig. 22 (b). Note that this clamping force produces a compression in the metal at the sides of the hole (since the metal tends to flow towards the center of the hole) and hence may be expected to reduce the high tensile stress at the sides of the hole caused by the axial forces. For a member in tension, this clamping force should be beneficial.

* Associate professor of structural engineering.
** Research associate.
*** Associate professor of civil engineering.

3. Failures do not occur more often at the top of the floorbeam in through trusses due to the reinforcing effect of the gusset or fill which almost always extends up the hanger above the floorbeams or floorbeam bracket.

5. Probable Remedy

In light of the above reasoning, the remedy would lie in the following:

1. Eliminate the bearing of rivets or bolts on the two lowest lines of rivets in the upper chord gussets.
2. Retain the beneficial effects of clamping force in these two lines of holes.
3. Make sure that all other stress raisers at these holes are eliminated as far as possible.

Probably the remedy will lie in the following:

1. Replace the rivets in the two lower lines of holes in the upper chord gussets with high-strength bolts which will be about ⅛ in. smaller in diameter than the holes and hence will never bear on the metal.
2. Tighten these bolts up to a controlled high clamping force, perhaps greater than that now expected from rivets.
3. Ream out the holes for these bolts so that the metal is smooth and unscratched, and also smoothly fillet the edges of the holes to a depth of about 1/16 in. Also see that contact surfaces of hanger and gussets are smooth and free of paint, mill scale, or grit at these holes.

6. Exploratory Fatigue Tests with High Clamping Bolts

In order to study the possibilities of the above proposal, some exploratory or pilot fatigue tests were made at Purdue. These are summarized in Fig. 24. The hole diameters were 1 in. The bolts were 1 in. diameter at threads and ⅞ in. diamter through the shank. Nuts were turned up to a torque of about 1000 ft-lb. Failure occurred by progressive fracture in the metal just under the edges of the bearing nuts, about ¼ in. below the edges of the holes and the cracks did not pass through the holes. In no case did slip occur prior to failure.

7. Other Laboratory Investigations

Test of Model of Floorbeam Hanger Frame.—A scale model of the rigid frame composed of the hangers, floorbeam, and upper chord gussets has been made and is being tested for the purpose of checking methods of rigid frame analysis. See Fig. 25.

Stress Concentrations and Fatigue.—Laboratory studies, both static and fatigue, of the stresses in riveted connections of plates and the fatigue strength of such connections are being carried on at Purdue by Mr. Carter. Present results indicate that the use of nonbearing high-strength bolts in the lower lines of rivets connecting the hangers to upper gussets, together with a high clamping force in the bolts and proper design of washers, etc., may prove to be much superior to rivets in these holes.

8. Unsolved Problems

There are many problems yet to be solved before it is certain that the above remedy is the correct one and before it may be safely tried. Among the questions to be settled are:

1. How much clamping force is desirable?

   Too much may produce high bi-axial strain and lower the fatigue strength of the metal just outside of the bolt holes.

(c) It appears that the end rivets will usually slip until they come to bear on the material and will henceforth carry load through shear and bearing but that the interior rivets will probably never come to bear but will carry load only through clamping force and friction.

In a bridge, the gusset is quite wide near the top of the hanger and can have only a small unit stress and hence will stretch to a negligible amount. Thus it appears that the rivets near the upper end of the connection will never come to bear at all under working loads, but will transfer stress only through clamping and friction. A full scale test of a hanger connected to the U_1 gussets and joint would seem desirable to obtain more information on this subject.

From the above, it may be concluded that:

1. Strain concentrations due to holes in hanger are real.
2. Clamping force is beneficial for a tension member.
3. Rivet bearing at the top of the hole causes high tensile stress at the sides of the hole directly proportional to bearing stress.

To further test the above, the results of some exploratory fatigue tests are shown in Fig. 24. This figure shows:

1. The riveted joint having a splice plate on one side only, i.e., with rivets in single shear, develops failure at stresses considerably larger than those producing failures in the bridge hangers.
2. The bolted joint having a splice plate on one side only and having no clamping force, develops failure at greatly reduced stresses and after a relatively few cycles of loading, i.e., at stresses of about the magnitude of those producing failures in the bridge hangers.

   Other tests, not shown in Fig. 24, on riveted joints having splice plates on each side of the plate, i.e., with rivets in double shear, did not produce failure even after millions of cycles of high stress.

3. The effect of impact loads upon stress concentrations at the sides of the rivet holes.

Field tests seem desirable here.

4. Working Hypothesis to Explain Fatigue Failures in the Hangers

It seems highly probable that the principal source of the high stress or strain concentrations which result in the low fatigue strength of the hangers is the bearing of the rivets at the top of the rivet holes at the failure section, probably occurring in most cases with rivets which have lost, or have never had, their clamping force.

In further support of the above, the following should be noted:

1. While it is recognized that hot-driven rivets probably do not fill the holes in most cases, it seems likely that the rivets at the lower edge of the gusset actually bear on the material in many cases. This must be particularly true when the clamping force is low.
2. The strains at the sides of the holes attributable to rivet bearing are so large that they will dwarf all other causes when they occur. This explains why many failures occur in the angles towards the track while the computed stress is greater in the outside angle, etc.

2. What is the effect of the thickness of the material, diameter of hole, etc., upon the strains in the metal produced by clamping force?

   Small surface irregularities may produce large bending stresses in a thick plate.
3. What is the effect of clamping force on load and stress distribution in the riveted joints?

   This may be of more importance than the strains produced by clamping in many cases.
4. Will the proper clamping force permanently prevent slip under the impact and vibration loads the hanger must regularly carry?
5. What is the proper diameter and thickness of the washers under the heads and nuts of these bolts?
6. What is the precise relation between stress or strain concentration and fatigue strength in the hangers?
7. What should be the form of hanger cross section?
8. What should be the design of the connections of the hanger to the floorbeam to prevent fatigue failure there?
9. What is the proper method of analysis of the bending stresses in the hanger due to floorbeam and stringer deflection?

IV. Field Investigations

1. Reduction of Stress Raisers at Copes—Pin-Connected Spans

The stress measurements shown in Figs. 26 (a) and 26 (b) were undertaken to demonstrate the feasibility of reducing the stress concentrations at the copes of existing pin-connected hangers. The work was done on the 124-ft. 2-in. span of the Atchison, Topeka & Santa Fe Railway bridge near Ponca City, Okla., in the summer of 1949 by M. B. Scott, J. W. Cox and H. H. West.*

As shown in Fig. 26 (a) the existing cope was filed to about a 3/32-in. radius to permit the installation of 1/16-in. SR-4 strain gages. Measurements taken with these gages indicated stress concentrations as high as 32,900 psi. when the locomotive was placed to produce maximum load in the hanger. Since the average measured unit stress on the gross area of the hanger was 8.98 ksi. at this load, the above 32.90 ksi. represents a local stress concentration of 3.67 times the average.

The sharp re-entrant cope was then eliminated by cutting the flange to a smooth curve of large radius as indicated in Fig. 26 (b). The stress concentrations under the same loading were then measured and found to be about 16,500 psi. This altering of the cope thus produced a marked reduction in local stress concentrations.

It should be noted that in many cases the actual re-entrant cope angle would probably be much more sharp than the 3/32-in. radius used in the tests, thus increasing the strain concentrations at such points to values much above those corresponding to the 32,900 psi. measured here.

It should be noted also that the procedure used here to secure stress relief at these copes is extremely simple and could easily be applied to existing structures. Two essential requirements of success in such stress relief are that the final cut should be of large radius and smooth and free of irregularities and also that the cut must be carried down into solid metal and well below any cracks, slag, or other imperfections. If a torch is used, the cut should extend at least ¼ in. below the burnt metal.

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* AAR research staff.

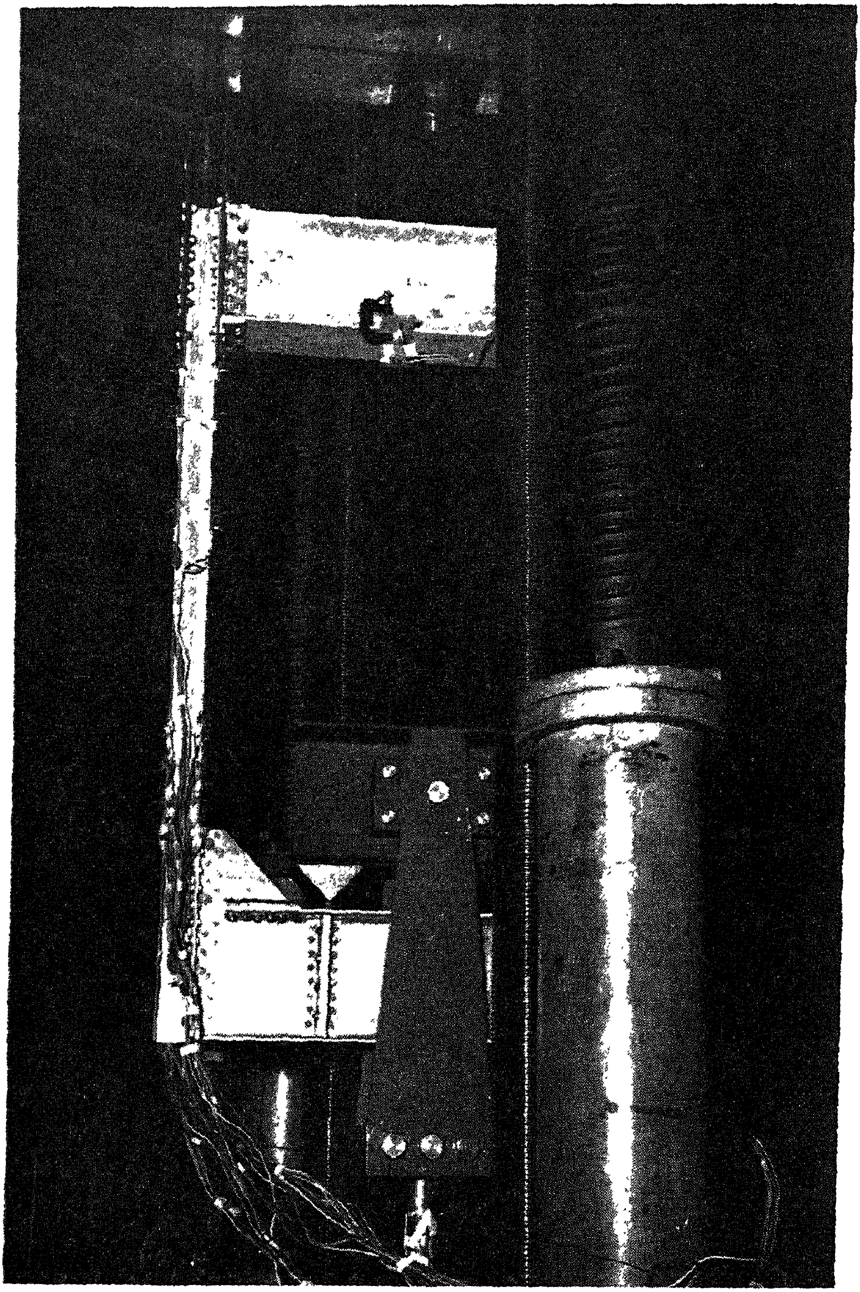


Fig. 25.—Scale Model of Floorbeam and Hanger Frame Set Up in Testing Machine.

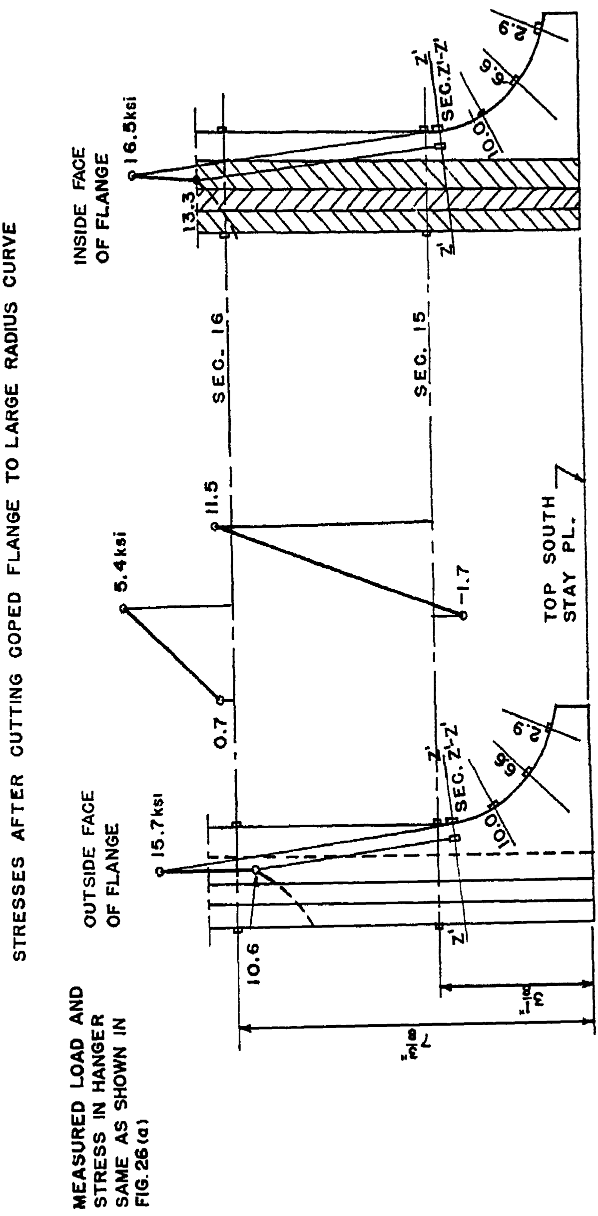


FIG. 26 (b)
MEASURED STRESSES – LARGE RADIUS CURVE

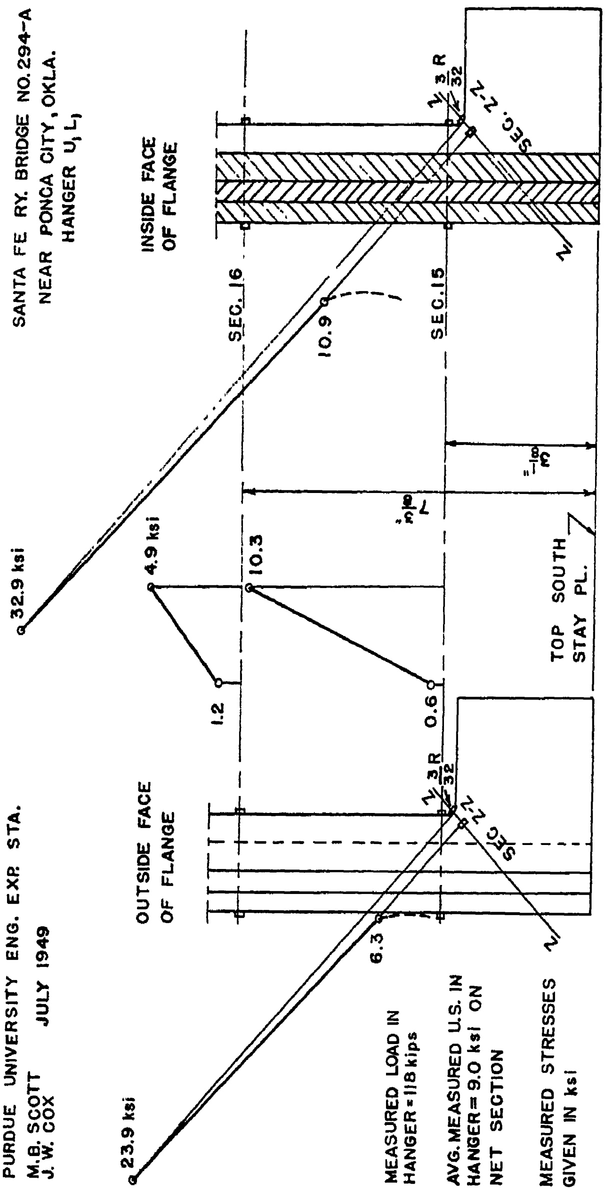


FIG. 26 (a)
MEASURED STRESSES — SMALL RADIUS CURVE

design method,[1] had not been developed to the point that it could be used on large diameter, field bolted structures.

Having somewhat exhausted the theoretical possibilities, the committee has this year turned its attention toward the structural performance of existing field installations with the hope that their performance will show either that the present design practice is sound or that it should be revised. On August 22, 1949, G. M. Magee, research engineer, AAR, at the request of this committee wrote the chief engineers of all member railroads asking each to report the deflections of a representative number of structures five feet or more in diameter along with all other pertinent information.

Data from this questionnaire are being assembled but the quantity of data at this time is insufficient to make any predictions. However, the committee feels that when all the field data are accumulated and studied the question of verification can be answered. These data should be available by early 1950.

Possible need for modification of the specification is influenced by a new factor. In 1944 when the subject specification was adopted three manufacturers were making plates with the same 6 in. by 1½-in. corrugation. At that time the design could be expressed in terms of gage. Since then, the original corrugation has been abandoned by most producers.

Now three producers of structural plate are each making a different shaped corrugation with different physical properties; all with greater strength than the original section.

The American Association of State Highway Officials has recognized the problem of modifying its specification for structural plate so as to take into account the different strengths of the three corrugations. To determine a basis of modification, it has instituted a cooperative investigation with the Michigan State Highway Department. The testing is being done at the laboratory of the Michigan State College, East Lansing, Mich., under the direction of E. A. Kinney.

Some members of the subcommittee spent a day in the laboratory observing tests and discussing various phases of the investigation. This investigation should be completed early in 1950.

It is recommended that this committee study the findings of the investigation being made at Michigan as soon as the results are available. This study along with the results of the field inspection that is now in progress should make it possible to arrive at a definite recommendation in the 1951 report. Until then, it is recommended that the specification be left in the Manual without change. As an aid to the engineer in the interim, the following addition to the present specification is suggested:

> Article 12, page 1–12.84, of the specification should be amended by adding the following paragraph:
>
> Alternate structural units having a depth of more than 1½ in. may be used in lieu of the plates specified herein under the following conditions:
>
> (a) The section modulus shall be equal to or greater than that of the plate specified. (b) The bolts shall be ¾ in. in diameter. (c) The number and arrangement of the plates and the size of the structures shall be recognized manufacturer's standards. (d) The minimum gage of side and top plates shall be as follows:

Dia. of Pipe: In.	*Gage of Plates*
60 to 90	10
91 to 120	8
121 to 150	7
151 to 180	5

[1] Ibid.

2. Other Field Investigations

1. The report on the field study made of the stresses in the Illinois Central Railroad bridge at Galena, Ill., was published in the AREA Bulletin 482, September–October 1949.

2. An experimental study of static and dynamic stresses in the hangers and connecting truss members of the Missouri–Kansas–Texas Lines 200-ft. single track through span at Erie, Kans., was made by Purdue and AAR research staff in 1948. The hanger section is a wide flange beam. The analysis of this work is under way at Purdue.

3. An experimental study of static and dynamic stresses in the hangers of the Wax Lake 400-ft. single track through truss span of the Texas & New Orleans Railroad, near Calumet, La., was made by the AAR research staff in 1948. The hanger section is composed of a web plate and four angles. The analysis of these data at Purdue is nearing completion.

4. An experimental study of static and dynamic stresses in the hangers of the Missouri–Kansas–Texas 124-ft. 5¼-in. single track span, near Denison, Tex., was made by the AAR research staff in 1948. The hanger section is a wide flange beam reinforced by a cover plate on the inside flange. The analysis of these data has been begun.

5. An experimental study of the static and dynamic stresses in the hangers of two truss spans, 122 ft. 9¾ in. and 125 ft., of the Texas & Pacific Railway near Mineral Wells, Tex., was made by the AAR research staff in 1949 at the request of the railroad. The data were analyzed by the railway and permission has been granted to publish the results.

6. An experimental study of the static stresses in a hanger of the Santa Fe Railway 124-ft. 2-in. single track through pin-connected span near Ponca City, Okla., was made in 1949. The hanger section is composed of two channels laced. The analysis of this work has been begun at Purdue.

Report on Assignment 8

Design of Metal Culverts of 60-In. Diameter and Larger, Including Corrugated Metal Arches

J. F. Marsh (chairman, subcommittee), Frank Baron, H. F. Bober, F. H. Boulton, Jr., R. N. Brodie, V. R. Cooledge, C. E. Ekberg, N. E. Hueni, D. V. Messman, Cornelius Neufeld, O. K. Peck, C. E. Sloan, H. F. Smith, G. L. Staley.

This progress report, submitted as information, deals with the verification or modification of the design data (gage tables for pipe) in the Specifications for Corrugated Structural Plate Pipe and Arches as adopted on the recommendation of Committee 1—Roadway and Ballast, in 1944 and as now printed in the Manual.

Your committee's report in the Proceedings, Vol. 50, 1949, pages 449 to 451, presented data on two theoretical approaches and gave consideration to a rational approach developed by A. G. Spangler on the Structural Design of Flexible Pipe Culverts.[1]

The two theoretical approaches, one based on the stress analysis of the upper half of a deflected pipe considered as an arch with fixed ends, and the other based on finding the value of (q), the ratio of lateral to vertical pressure, in Talbot's equation[2] both verified the reasonableness of the existing design data. It was reasoned that the rational

[1] Iowa Engineering Experiment Station Bulletin No. 153.

[2] Illinois Engineering Experiment Station Bulletin No. 22.

4. The bolts installed in the enlarged and dished out holes in the Pennsylvania bridge at Perryville, Md., with only one washer under the head and nut could not be kept tight as the washers deflected excessively under the high clamping force.

5. The bolts in the diaphragms of the Pennsylvania beam span bridge at Naaman, Del., remained tight but some of the rivets at the opposite end of the diaphragms had worked loose during the year.

6. A visual inspection of all the bolts did not reveal any evidence of cracked paint, rust or slippage of the members, except at those locations where the bolts had not been properly installed.

7. A check on the tightness of a representative number of bolts with the torque wrench revealed that the majority of the bolts have retained their original clamping force. Some of the bolts appear to have lost some of their clamping force but it is not known whether the bolts were not properly tightened when installed or whether the bolted members are re-seating themselves.

2. Foreword

The investigations conducted by various laboratories to determine the static and fatigue strength of riveted joints connecting structural steel plates, have clearly shown that the rivets do not completely fill the holes in these plates. It is generally agreed that the load is transferred from one plate to the other by friction between the plates resulting from the clamping action of the rivet heads. The magnitude of the clamping force exerted by the heads of various length rivets was investigated by Prof. W. M Wilson and the results published in University of Illinois Bulletin 302. Prof. Wilson found that the clamping force increased with an increase in the grip of the rivet. The fact that the load carrying capacity of a structural joint depends upon the magnitude of the friction between the plates resulting from the clamping forces of the rivet heads and not upon the degree of filling the hole by the shank of the rivet indicated to Prof. Wilson that a structural fastener, such as high-strength bolt, capable of exerting a high clamping force would be superior to a rivet. Prof. Wilson's exploratory fatigue tests on structural joints fastened by high-strength bolts appreciably smaller than the holes in the plates supported this hypothesis, provided the nuts were screwed up to give a high tension in the bolts.

It has been found in recent tests conducted at Northwestern University and reported in the Proceedings, Vol. 51, 1950 (Bulletin 481) page 1, that the fatigue strength of structural joints fastened with high-strength bolts was greater than that found for similar joints fastened with either hot or cold driven rivets.

The bolting of a structural joint is considerably more economical than the riveting of the joint, especially in field construction, and since the exploratory research has indicated the superior qualities of a bolted joint, the Research Council on Riveted and Bolted Structural Joints has initiated an extensive program to obtain laboratory data so that a design specification covering their use can be written.

It was realized that before the use of high-strength bolts in place of rivets would be accepted by the railway bridge engineers, it would be necessary to determine if the bolts would stay tight in bridges under normal operating conditions where the members are subjected to considerable vibration. Accordingly, the research staff of the AAR arranged with several of the railroads to replace rivets with high-strength bolts at particular joints where trouble had been encountered in keeping rivets tight. High-strength bolts were also used to connect diaphragm plates to stiffener angles in a new beam span and also in a repair job to the floorbeam hangers of a pin-connected truss span.

Report on Assignment 9

Use of High Strength Structural Bolts in Steel Railway Bridges

A. G. Rankin (chairman, subcommittee), Frank Baron, J. E. Bernhardt, W. E. Dowling, R. B. Hennessy, N. E. Hueni, C. T. G. Looney, H. C. Tammen.

Your committee submits, as information, the following progress report of field test installations of high-strength structural bolts.

The test installations were made by the research staff of the AAR at the request of your committee to determine if such bolts will retain their clamping force in structural joints subjected to vibrational loads. Your committee feels that it must have the final results of these test installations before it can proceed with the preparations of a specification covering their use in railroad structures.

1. Digest

The action of a structural joint in transferring a load from one member to another by means of a fastener has been of interest to research engineers for many years. It is now generally agreed that cold or hot driven rivets do not completely fill the holes in structural members but provide a certain amount of clamping force between the rivet heads so that the load is transferred from one member to the other by friction. Laboratory investigations have shown that greater clamping forces can be secured by the use of high-strength bolts in place of rivets and also that joints fabricated with these bolts are superior to joints fabricated with rivets.

In order to determine if the use of high-strength bolts was practical in railroad structures, the research staff of the AAR supervised the installation of over 1000 bolts of various sizes and lengths in about 20 different types of joints on 12 different bridges. The greater part of these installations were made in bridge joints where considerable trouble had been encountered in keeping rivets tight on account of the vibration in the members.

The results of these field installations are of particular interest to the bridge engineer for the bolting of a joint is more economical than the riveting of a joint, especially in field construction, and more particularly in small or remote structures where the necessary riveting equipment is not readily available. Further, it obviously would be more economical to use high-strength bolts as erection or fitting up bolts and leave them in place during the field erection of new structures rather than incur the expense of their removal and replacement with rivets.

The test installations of the high-strength bolts have only been in service for about a year but the following comments can be stated as a result of the recent inspection of all the bolts:

1. The high-strength bolts installed with common washers in place of hardened washers in the ore docks at Ashtabula, Ohio, did not stay tight. The same bolts installed with hardened washers in the same holes have stayed tight.
2. The bolts installed in the lateral bracing connection of the Hulett ore unloader at Cleveland, Ohio, have remained tight but the new rivets in the connection at the other end of the same member have worked loose.
3. The bolts installed in the enlarged and jagged holes in the Pennsylvania bridge at Bellevue, Md., with two hardened washers under both the head and nut retained their full clamping force.

4. Installation of Bolts

The general procedure that was followed in making the test installations of the bolts was to first remove the rivets at the locations previously selected by either knocking or burning off the rivet heads, backing out the rivets and then cleaning the steel surface around the hole. The high-strength bolts were then installed with a hardened washer under the head and nut. The bolts were then tightened to the approximate clamping force by the ratchet wrench shown in Fig. 1. The correct amount of torque to develop the desired bolt tension or clamping force was then obtained by the use of the torque wrench shown in Fig. 1, making sure that the torque reading was taken when the nut was still turning on the bolt, since there is a considerable difference between the static and sliding coefficient of friction.

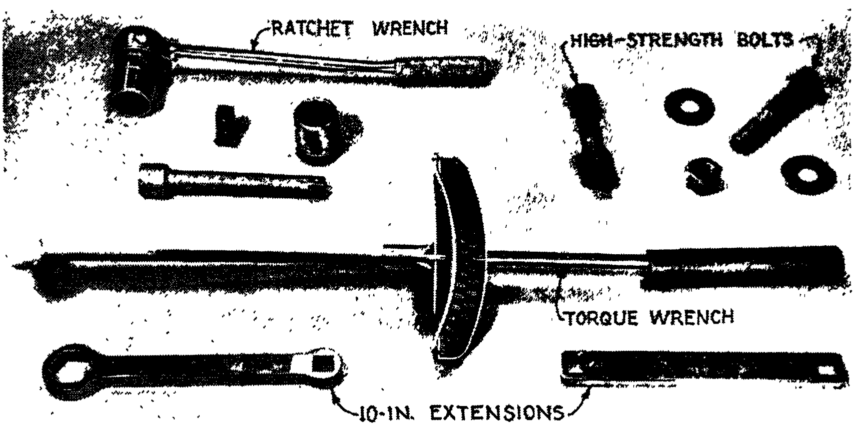


Fig. 1.—Torque Wrench, Ratchet Wrench and Miscellaneous Attachments Required.

The torque wrench used in these installations and shown in Fig. 1 depends upon the deflection of the handle arm to measure the amount of torque, and for a torque of 450 ft.-lb., the end of the handle arm will deflect about 15 in. As a result of the deflection of the handle arm there were several locations, such as the top and bottom bolts in diaphragm plates between deep beams, where it was impossible to use the wrench in tightening the high-strength bolts, so these bolts were tightened with the ratchet wrench to the approximate torque.

The high-strength bolts were installed with only the hardened washers under the head and nut and no lock washers or burring of the threads were used to keep the nut from turning. The nuts were kept on the bolts entirely by the friction resulting from the high clamping force. The bolt, washers and nut, however, were covered with a black paint upon completion of the installation to facilitate, during future inspections, detection of any loosening of the nuts.

The torque wrench has an effective length of 30 in. with a normal capacity of 450 ft.-lb. However, the capacity can be increased to 600 ft.-lb. by the use of the 10-in. extension. The wrench was purchased from the P. A. Sturtevant Co., Addison, Ill., and the cost, including extensions and sockets was $180.

The test installations of high-strength bolts described in this report were conducted under the general direction of G. M. Magee, research engineer, Engineering Division, AAR. The bolts were installed and inspected under the direct supervision of H. H. West, research staff. The conduct of the tests and preparation of the report were in charge of E. J. Ruble, structural engineer, research staff, AAR.

3. Bolts, Nuts and Washers

A subcommittee of the ASTM is preparing a tentative specification for high-strength bolts but since this specification was not available, the following requirements were specified in ordering the bolts, nuts and washers used in these tests:

1. The bolts shall be of American Standard Regular proportions, hexagonal in shape, and semi-finished to provide a good bearing surface under the head.
2. The nuts shall be semi-finished American Standard heavy and hexagonal in shape. The nuts shall have a minimum hardness of 121 Brinell (70 Rockwell B).
3. The bolts shall be quenched and tempered and shall have a minimum yield point of 85,000 psi. and a minimum tensile strength of 105,000 psi.
4. The threads shall be of the coarse-thread series as specified in the American Standard for Screw Threads having a Class 2 tolerance for both bolt and nut. The length of thread on the bolt shall be such that when the bolts are installed the face of the nut is not closer than three threads to the beginning of the shank.
5. The nominal diameter of the bolts shall be not less than 1/16 in. smaller than the diameter of the hole.
6. The washers shall be of a heavy flat type about 11/64 in. in thickness and shall be hardened by carburizing (not cyanide) to a minimum depth of 0.015 in. and to a hardness of 65–70 Rockwell A. The inside diameter of the washer shall be not more than 1/16 in. larger than the nominal bolt diameter.

The bolts can be purchased from any manufacturer with heat-treating equipment. The experimental bolts obtained for recent laboratory and field tests have been supplied by:

1. Russell Burdsall and Ward Bolt and Nut Company, Port Chester, N. Y.
2. Pittsburgh Screw and Bolt Corporation, Pittsburgh, Pa.
3. Bethlehem Steel Company, Lebanon, Pa.

The average costs of the bolts for the field tests were:

¾-in. dia. bolts	$0.13 each
⅞-in. dia. bolts	0.24 each
1-in. dia. bolts	0.28 each

The washers for the field tests were purchased from the Jones and Laughlin Steel Co., Chicago, Ill. and were hardened by the Lindberg Steel Treating Co., Chicago, Ill. The cost of the washers was:

	Per 100
Plain ⅞-in. dia. washer	$1.60
Hardening	1.50
Total	$3.10

INSPECTION OF BOLTS ON MAY 27, 1948

The ⅞-in. dia. bolts at Sections B–B and C–C were visually inspected and all bolts appeared to be tight as there was no evidence of rust or working of the members. However, when the torque wrench was applied to each bolt, the following conditions were noted:

Bolt 1 turned at a torque of 400 ft.-lb.
Bolts 2 to 11, incl., did not turn at a torque of 470 ft.-lb.
Bolt 12 turned at a torque of 400 ft.-lb.
Bolt 13 turned at a torque of 340 ft.-lb.
Bolt 14 turned at a torque of 250 ft.-lb.
Bolt 15 turned at a torque of 320 ft.-lb.
Bolt 16 turned at a torque of 400 ft.-lb.
Bolts 17 to 20, incl., did not turn at a torque of 470 ft.-lb.
Bolt 21 turned at a torque of 400 ft.-lb.
Bolt 22 turned at a torque of 300 ft.-lb.
Bolt 23 turned at a torque of 220 ft.-lb.
Bolt 24 turned at a torque of 100 ft.-lb.

The clamping force in these bolts was undoubtedly somewhat below the force indicated by the torque wrench at the time the nut turned as some of the torque was required in overcoming static friction. All of the bolts at this joint were retightened to a torque of 470 ft.-lb.

The ¾-in. dia. bolts at Sections D–D and E–E did not show any evidence of losing their clamping force. The bolts were checked with the torque wrench and not a nut would turn at a torque of 295 ft.-lb.

INSPECTION OF BOLTS ON SEPTEMBER 20, 1949

A visual inspection was made of all the bolts and joints to look for new rust, cracked paint or any other sign that the bolts were loose or the members slipping but no evidence of failure could be found.

Each bolt in the stringer connection, Sections B–B and C–C, was checked with the torque wrench and not a nut would turn at a torque of 480 ft.-lb. The torque on bolt 13 was slowly increased to 600 ft.-lb. before the nut started turning. The nuts on bolts 2, 6 and 11 were marked to show their relative position with the bolt and then backed off one full turn. A torque of 520 ft.-lb. was required to start the nuts turning on bolts 2 and 6 and 560 ft.-lb. for bolt 11. The three bolts were then tightened to a torque of 480 ft.-lb. which returned the nuts to their original position.

The bolts at the gusset plate connection to the post, Sections D–D and E–E, could not be checked with the torque wrench as no scaffold was available for this inspection. However, all the bolts appeared tight and there was no evidence of slippage.

Pennsylvania Railroad—Ohio & Western

Pennsylvania Dock Company at Cleveland, Ohio

The structure shown in Figs. 3 and 4 is a Hulett ore unloader and is used to unload the iron ore from the lake barges. This structure is subjected to a large number of stress cycles as it is used continuously during the navigation season.

The particular joints selected for the test installations are shown on Figs. 3 and 4. The rivets in these joints have been working loose at frequent intervals and it has been necessary to redrive them about every year.

The bolts were tightened, in most cases, to develop a unit stress on the mean thread area of the bolt equal to 85 percent of the yield point of the steel, or 72,250 psi. The clamping force of the bolt is then a product of the unit stress and the mean thread area. The mean thread areas of the bolts are:

Bolt Size	*Threads per in.*	*Nominal Area*	*Mean Thread Area*
¾	10	0.4418	0.3344
⅞	9	0.6013	0.4617
1	8	0.7854	0.6057

The torque required to tighten the bolts to the desired clamping force can be determined from the following empirical equation which has been verified by tests reported in the Proceedings, Vol. 51, 1950 (Bulletin 481), page 8:

$$\text{Torque (foot-pounds)} = \frac{0.2 \text{ Clamping force (pounds)} \times \text{nominal bolt diameter (inches)}}{12},$$

and is equal to the following values for the bolt sizes shown:

Bolt Size	*Clamping Force Lb.*	*Torque Ft.-Lb.*
¾	24,200	300
⅞	33,300	486
1	43,600	730

5. Results of Field Tests

Arrangements were made with several railroads to install high-strength bolts in various types of connections of both old and new bridges. However, special emphasis was placed on selecting connections where trouble had been encountered in keeping rivets from working loose. The bridges selected and the results of the test installations are:

Pennsylvania Railroad—Ohio & Western

Pennsylvania Dock Company at Ashtabula, Ohio

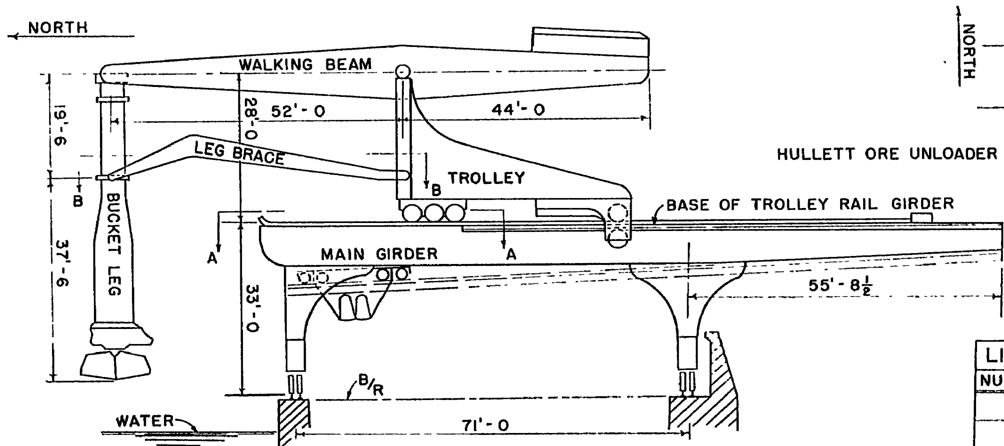
The structure shown on Fig. 2 carries the machinery used in unloading the iron ore from the lake barges. The ore unloading machinery is used continuously during the navigation season, so that the structure is subjected to a large number of cycles of stress.

The locations of the test installations of the high-strength bolts are shown on Fig. 2 and these particular joints were selected as considerable trouble has been encountered in the past in keeping rivets tight at these locations. It has been necessary to redrive the rivets at these particular locations every year at considerable expense.

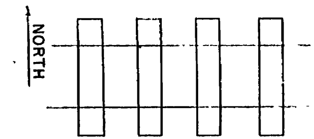
Installation of Bolts on March 19, 1948

The twenty-four ⅞-in. dia. bolts installed at the connection of the trolley stringers to the hanger gusset plate, Sections B–B and C–C, were tightened to a torque of 470 ft.-lb. with the torque wrench to secure the proper adjustment of each bolt.

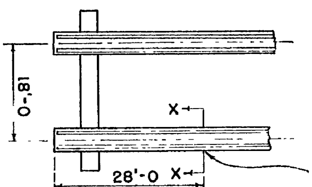
The ¾-in. dia. bolts installed at the gusset plate connection to the post, Sections D–D and E–E could not be properly tightened with the torque wrench at this time as the available socket attachment on the wrench would not fit the bolts. The bolts were temporarily tightened to the estimated torque with a regular open-end wrench. The bolts at this location were too long so it was necessary to use common washers as fills under the hardened washers at both the bolt head and the nut.



ELEVATION
HULLET ORE UNLOADER

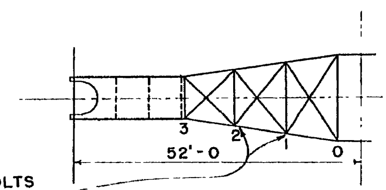


LIST OF BOLTS & WASHERS			
NUMBER	SIZE	GRIP	LENGTH
18	$\frac{7}{8}\phi$	$2\frac{5}{8}$	5
22	$\frac{7}{8}\phi$	$1\frac{1}{4}$	3
80	$\frac{7}{8}$ CARBURIZED WASHERS		
18	BEVELED WASHERS		



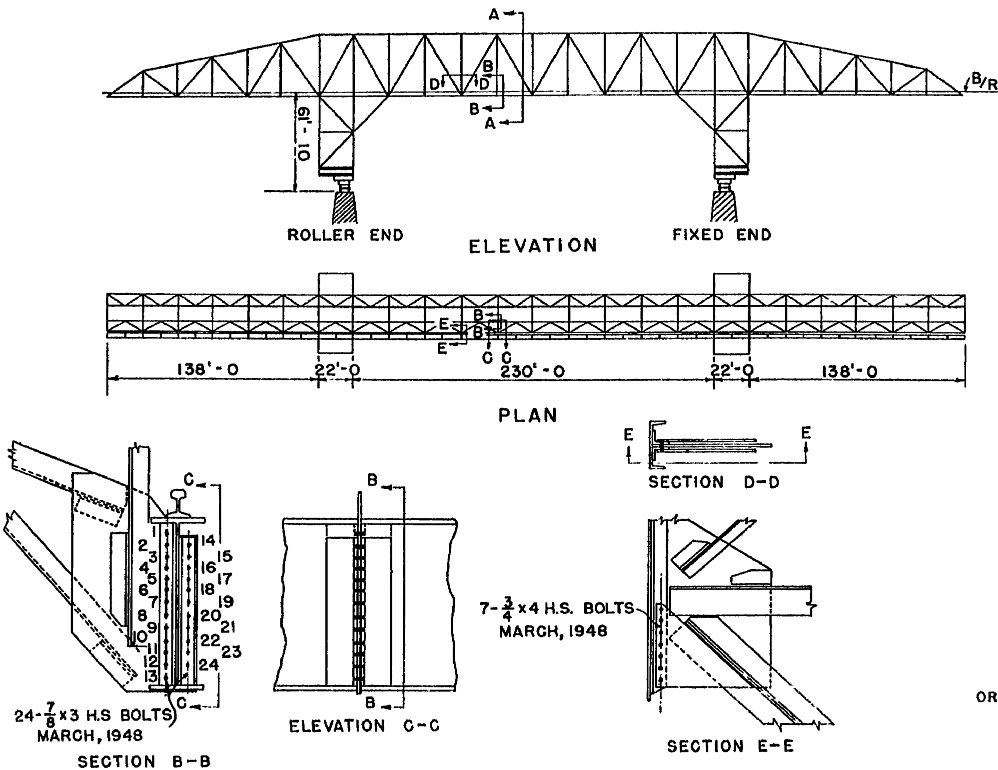
SECTION A-A
UNLOADER NO. 1

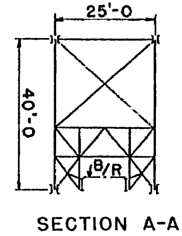
LOCATION OF H.S BOLTS
SEE FIGURE NO 4 FOR
ENLARGED DETAILS



PLAN OF LEG BRACE
SECTION B-B
UNLOADER NO. 2

FIG. 3
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
ORE UNLOADER PENNSYLVANIA DOCKS
CLEVELAND, OHIO





LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
24	$\frac{7}{8}\phi$	$1\frac{1}{4}$	3
7	$\frac{3}{4}\phi$	$2\frac{5}{16}$	4
48	$\frac{7}{8}$ CARBURIZED WASHERS		
14	$\frac{3}{4}$ CARBURIZED WASHERS		

FIG. 2
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
ORE BRIDGE PENNSYLVANIA DOCKS
ASHTABULA, OHIO

Installation of Bolts on March 20, 1948

The eighteen ⅞-in. dia. bolts holding the 175-lb. rail to the top flange of the main girder, Section X–X on Figs. 3 and 4, were installed with a special beveled washer to fit the base of the rail. The hardened washers were not available for this installation so common washers were placed under the head and nut and each bolt tightened to an estimated torque of 480 ft.-lb. by a plain open-end wrench since the socket attachment on the torque wrench was not suitable.

The ⅞-in. dia. bolts in the lateral system of the leg brace at joints 1 and 2 of unloader No. 2, Figs. 4 and 5, were installed with common washers as hardened washers were not available at this time and then tightened to a torque of 470 ft.-lb. as measured by the torque wrench.

Inspection of Bolts on May 28, 1948

The eighteen ⅞-in. dia. bolts holding the crane rail to the girder, Section X–X, Fig. 4, were checked with the torque wrench and the nuts would not move under a torque of 470 ft.-lb. The common washers under the head and nut of the bolts were replaced by hardened washers and the bolts again tightened to a torque of 470 ft.-lb. as measured by the torque wrench.

The twelve ⅞-in. dia. bolts in the lateral system of the leg brace at joint 2, Fig. 4, had worked loose during the operation of the crane and it had been necessary for the maintenance men at the dock to tighten these bolts several times since their installation. The ten ⅞-in. dia. bolts at joint 1 were checked with the torque wrench and the nuts would not move under a torque of 470 ft.-lb. The common washers under the heads and nuts of all the bolts at joints 1 and 2 were replaced by hardened washers and then tightened to a torque of 470 ft.-lb. as measured by the torque wrench.

Inspection of Bolts on December 2, 1948

A visual inspection of the bolts holding the crane rail to the girder, Section X–X, Fig. 4, showed rust around bolts 1 and 2 and that bolts 11 and 12 were broken at the junction of the head and body, however, there was no evidence that the rail was slipping or working on the top flange of the girder. The bolts were then checked with the torque wrench and the nut on bolt 1 turned at a torque of 160 ft.-lb. and the nut on bolt 2 turned at 260 ft.-lb. The remaining bolts in the connection, except 11 and 12, withstood a torque of 470 ft.-lb. It should be pointed out that the 175-lb. crane rail is spliced close to these bolts with the ends of the joint bar over bolts 1 and 11.

The loose bolts were retightened to the original torque. The two broken bolts, Nos. 11 and 12 were replaced later by new ones and then tightened to the estimated torque by an open-end wrench. An etch test was made on the broken bolts to determine the soundness of the steel, which revealed it to be sound, free from pipe or seams Physical and chemical tests were also made on the bolts with the following results:

Yield strength	107,300 psi.
Tensile strength	120,800 psi.
Enlongation	19 percent
Reduction of area	60 percent
Carbon content	0.450 percent
Manganese content	0.840 percent
Phosphorous content	0.020 percent
Sulphur content	0.029 percent

The bolts in the lateral system of the leg brace appeared to be tight and there was no evidence of the channel slipping on the lateral plate. The tightness of the bolts

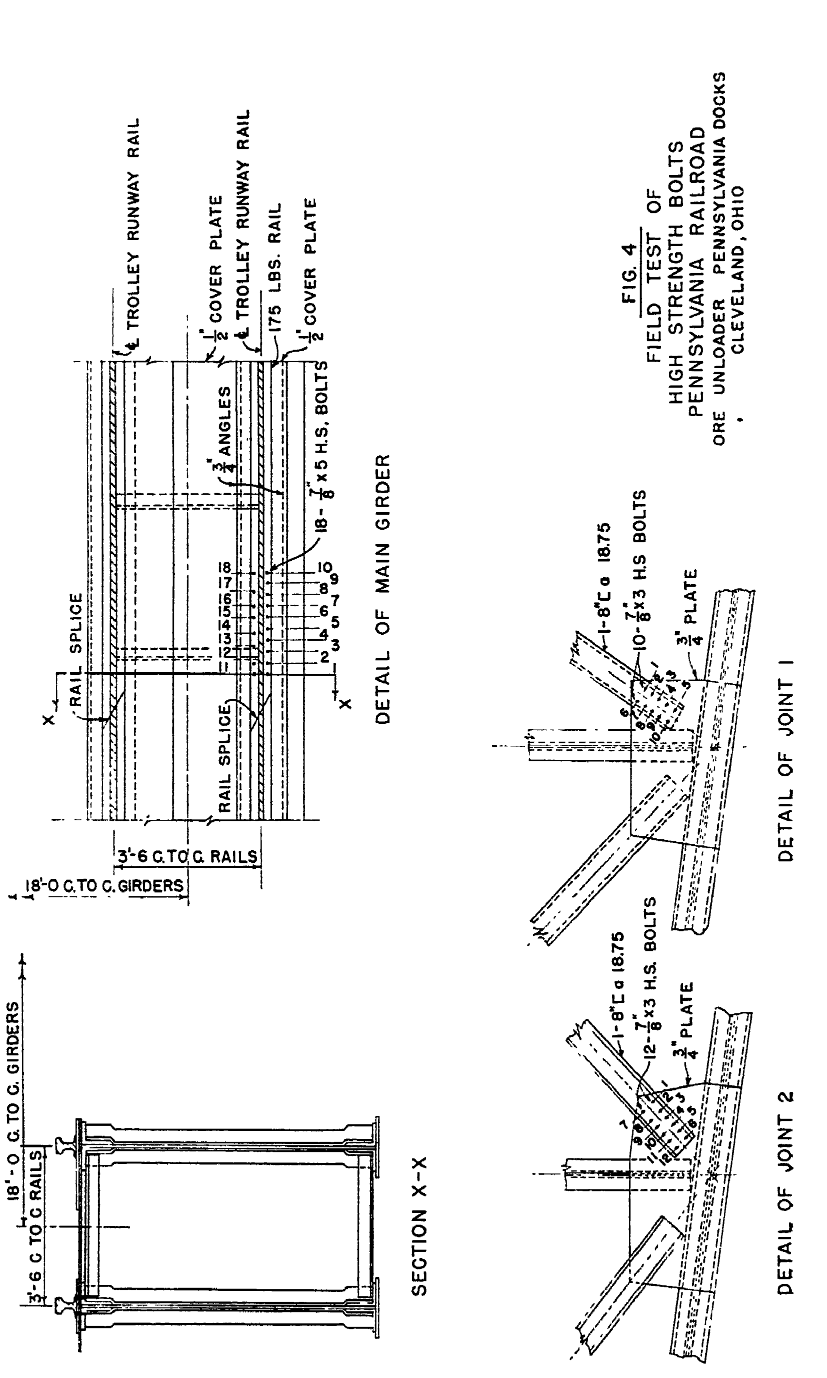
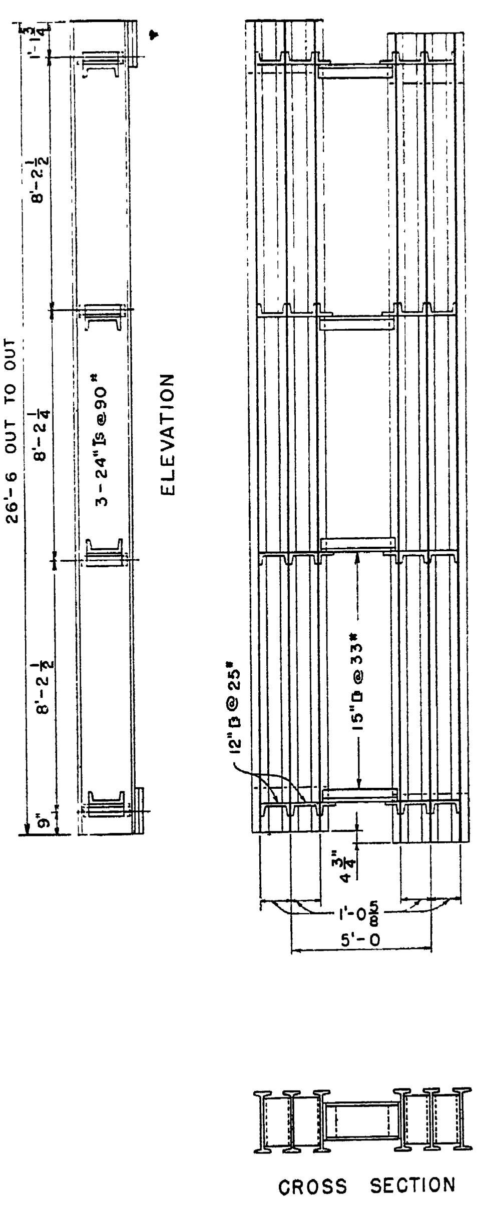


FIG. 4
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
ORE UNLOADER PENNSYLVANIA DOCKS
CLEVELAND, OHIO



TYPICAL SPAN

SEE FIGURE NO 6 FOR LOCATION OF TEST SPANS

FIG. 5
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
BRIDGE NO 2198 MARYLAND DIV.
BELLEVUE, DELAWARE

was checked with the torque wrench and no nuts moved under a torque of 470 ft.-lb., except those on bolt 1 and 6 of joint 1 which moved at a torque of 440 ft.-lb. These two bolts were tightened to the initial torque of 470 ft.-lb.

INSPECTION OF BOLTS ON SEPTEMBER 21, 1949

The bolts holding the crane rail to the girder, Section X–X, Fig. 4, were visually inspected for new rust spots, cracked paint, or slipping of the rail but there was no such evidence. Bolt 1 was found to be broken at the junction of the head and shank and the nuts on bolts 11 and 12 turned at a torque of 280 ft.-lb. The nuts on the remaining bolts did not turn under a torque of 480 ft.-lb. The torque was slowly increased on bolts 4 and 15 and the nuts moved at a torque of 520 ft.-lb. Bolts 11 and 12 were retightened to the original torque of 470 ft.-lb.

The broken bolt 1 was rusty and badly pitted so in order to determine if the shanks of the other bolts were in the same condition, bolt 5 was removed and examined. There was no rust on this bolt, indicating that the washer assembly, when properly tightened, prevents the water from getting into the bolt hole.

It should be pointed out that the bolts in the joint bars at the rail splices are not kept tight thus permitting some movement of the ends of the rail.

The bolts in the lateral system of the leg braces at joints 1 and 2 appeared to be tight from a visual inspection, however, the channel at joint 2 appeared to have slipped about 1/16 in. but there was no evidence that the channel was working back and forth. The bolts were then checked with the torque wrench but no movement of the nut was secured with a torque of 470 ft.-lb. The nuts on bolt 3 of both joint 1 and joint 2 were marked to show their relative position with the bolt and then backed off one full turn. The two bolts were then tightened to a torque of 480 ft.-lb. and the nuts returned to their original position.

It is of interest to note that while all the high-strength bolts connecting the 8-in. channel to the ¾-in. lateral plate at joint 2 have remained tight, the rivets connecting the other end of the channel to the lateral plate, worked loose during the year.

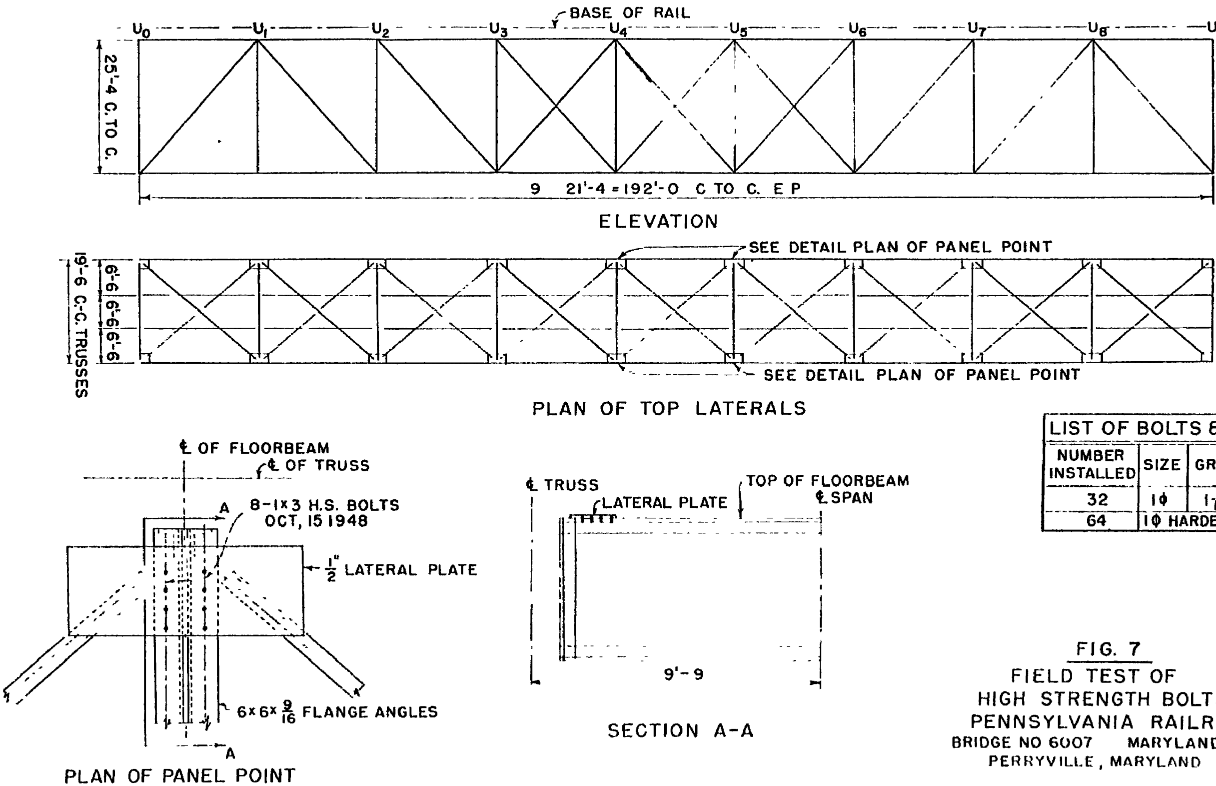
Pennsylvania Railroad—Bridge 21.98, at Bellevue, Del.

The bridge at this location consists of single-track beam spans under tracks 2, 3 and 4 and a deck plate girder span under track 1. The beam spans consist of three 24-in. I-beams per rail, having an overall length of 26 ft. 8 in. as shown on Figs. 5 and 6. The beams are diaphragmed with channels as shown.

Considerable trouble has been encountered in the past in keeping rivets tight in this bridge and a number of loose rivets had been replaced with common bolts. The rivet heads had been cut off with an aceteylene torch, resulting in a large jagged hole in the steel at these locations.

INSTALLATION OF BOLTS ON OCTOBER 11, 1948

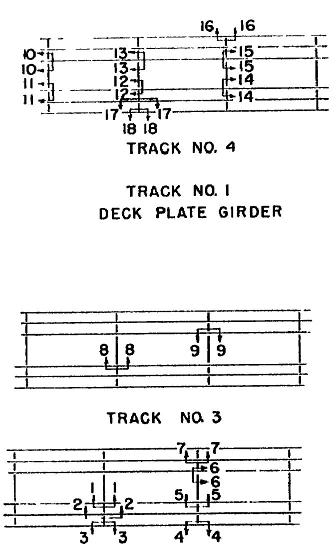
The ¾-in. dia. high-strength bolts were installed at all the locations shown on Fig. 6 and then tightened to a torque of 295 ft.-lb. The beveled washers detailed on Fig. 6 were used for all sloping channel flanges with the hardened washer between the beveled washer and the bolt head or nuts. The bolts represented by the solid circle were placed in normal holes with good bearing surfaces for the washers but the bolts represented by the "X" symbol were placed in enlarged holes. In order to reduce the bending in the hardened washer at the enlarged holes, two washers were used under the head and nut at these locations.

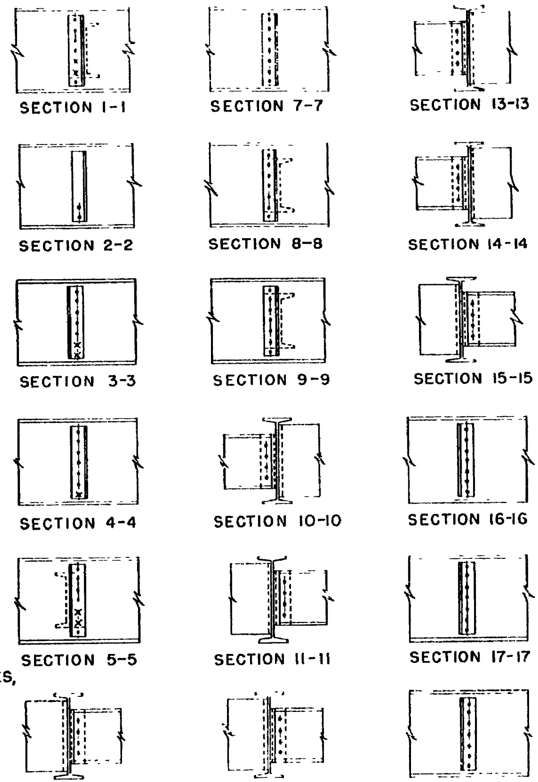


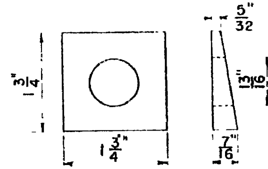
LIST OF BOLTS & WASHERS

NUMBER INSTALLED	SIZE	GRIP	LENGTH
32	1φ	1 1/16	3
64	1φ HARDENED WASHERS		

FIG. 7
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
BRIDGE NO 6007 MARYLAND DIV.
PERRYVILLE, MARYLAND







BEVELED WASHERS
STANDARD

NOTE.
• - INDICATES $\frac{3}{4}''$ DIA. HIGH STRENGTH BOLTS PLACED IN NORMAL HOLES, OCT. 11, TO OCT. 16, 1948
✕ - INDICATES $\frac{3}{4}''$ DIA. HIGH STRENGTH BOLTS PLACED IN ENLARGED HOLES, OCT. 11, TO OCT. 16, 1948

LIST OF BOLTS & WASHERS

NUMBER INSTALLED	SIZE	GRIP	LENGTH
28	$\frac{3}{4}$	$\frac{13}{16}$	$2\frac{1}{2}$
16	$\frac{3}{4}$	$1\frac{5}{8}$	$3\frac{3}{4}$
36	$\frac{3}{4}$	$1\frac{1}{8}$	3
20	$\frac{3}{4}$	$1\frac{1}{2}$	$3\frac{1}{2}$
200	$\frac{3}{4}$ HARDENED WASHERS		
88	BEVELED WASHERS		

FIG. 6
FIELD TEST OF
HIGH STRENGTH BOLTS
LOCATION OF BOLTS
PENNSYLVANIA RAILROAD
BRIDGE NO 2198 BELLEVUE, DIV
BELLEVUE, DELAWARE

The bolts were not replaced as it will first be necessary to provide a better bearing surface for the washers by either replacing the lateral plates or providing thick plate fills under the washers.

Pennsylvania Railroad—Bridge 18.58 at Naaman, Del.

The bridge at Naaman, Del., consists of single-track beam spans under the four tracks as shown in Fig. 8. The beam span consists of three 20-in. I-beams per rail, having an overall length of 23 ft. 6 in., as shown on Fig. 8. The beams are diaphragmed with channels as shown.

Considerable trouble has been encountered in the past in keeping rivets tight in this bridge and the rivets at all the locations shown on Fig. 8 had been removed and replaced with standard bolts which had failed to stay tight.

Installation of Bolts—October 1948

The positions for the installations of the high-strength bolts were marked by the representative of the AAR on October 15, 1948, but the railroad was unable to install the bolts at this time. The torque wrench was left with the railroad and the bolts were installed a few days later by the same gang of men who had made the installation at Bridge 21.98 at Bellevue, Del.

Inspection of Bolts on September 8, 1949

A visual inspection of all the bolts did not reveal any rust spots, cracked paint or slippage of the member at the connections. The clamping force could not be checked with the torque wrench as scaffold was not available for this inspection.

The three bottom bolts at Section B–B, Fig. 8, and the top bolt at Section A_2–A_2 had broken and fallen out of the hole. The failure of these bolts is attributed directly to an error in the installation. To correct for the slope of the channel leg on one side of these connections, the beveled washers, detailed on Fig. 8, were provided for installation under the hardened washers; however, when the bolts were erected, the beveled washers were not used at these two sections.

The bolts at Section A–A were installed with beveled washers under both the head and nut of the bolt, but it can be seen that only one beveled washer was required. Considerable bending has occurred in the bolts at this section but, so far, none of the bolts has broken.

New bolts will be ordered for these three sections and then installed with the correct number of beveled washers.

It was interesting to note that all the rivets at the opposite end of the 12-in. channel at Section B–B were found to be loose during this inspection although they were tight when the bolts were installed in 1948.

New York Central System—Bridge 73.63 at Ade, Ind.

The double track through bridge at Ade, Ind., consists of two outside plate girders and one center plate girder having an overall length of 45 ft. back to back of angles, as shown on Fig. 9.

The original rivets connecting the ¾-in. plate knee-braces to the ⅜-in. angles, as shown at Sections A–A, A_2–A_2 and A_3–A_3, Fig. 9, had worked loose, so standard bolts were tried without success. It has been necessary to maintain a close inspection of the common bolts, retightening loose bolts and replacing lost bolts at frequent intervals.

The two lower rivets of the group connecting the diaphragm to the beam shown in Section 2–2, Fig. 6, were the only loose rivets in this group, so bolts were installed in only these two holes. This affords a comparison of a partially riveted and bolted joint with one that is fully bolted.

INSPECTION OF BOLTS ON SEPTEMBER 8, 1949

A visual inspection of all the bolts did not reveal any rust, cracked paint or slippage of the members at the connection. The torque wrench was then used on about 25 bolts, selected at random, and only one bolt started turning at a torque lower than 295 ft.-lb. The nut on the top bolt at Section 1–1, Fig. 6, started turning at a torque of 240 ft.-lb. No explanation can be given for the low tension in this bolt, except that it may not have been tightened the correct amount when installed. The bolt was retightened to the correct torque of 295 ft.-lb.

The nuts on several bolts, selected at random, were marked to show their relative position with the bolt and then backed off a full turn. The bolts were then re-tightened to their original torque of 295 ft.-lb. and the nuts returned to their marked position.

It is interesting to note that the bolts with the double washers installed in the enlarged holes retained their full clamping force.

Pennsylvania Railroad—Bridge 60.07 at Perryville, Md.

The bridge at Perryville, Md., consists of a double-track deck truss span having a span of 192 ft. center to center of bearings, as shown on Fig. 7. The ties of each track are supported at one end on a stringer while the other end of the tie rests on the top chord. The structure was built in 1904 and was designed for light loads.

The locations for the test installations, as shown on Fig. 7, were selected, as it has been impossible to keep the ½-in. lateral plates firmly attached to the floorbeams. The plates were originally fastened with ⅞-in. dia. rivets but these would not stay tight. The plates were welded to the floorbeam but the welding soon broke. Standard bolts were then installed with the nuts welded to the bolts but the working of the joints enlarged the holes to over 1-in. diameter. The action of the bolts not only enlarged the holes but also dished out the surface under both the head and nut of the bolt.

INSTALLATION OF BOLTS ON OCTOBER 13, 1948

The 1 in. dia. high-strength bolts were installed at the locations shown on Fig. 7 after considerable trouble. As the bolts were tightened, the washers were drawn down into the dished out surface, causing many of the washers to break. The bolts were removed and the surface around the holes heated and then hammered to provide a better bearing surface for the washers.

In order to stress the 1-in. dia. bolts to 85 percent of the yield strength, a torque of 730 ft.-lb. must be applied to the bolt. The capacity of the torque wrench is 600 ft.-lb., so in tightening these bolts it was necessary to have two men apply this estimated force on the end of a 3-ft. pipe extension on the handle of the socket wrench. Several bolts were checked with the torque wrench and the applied torque exceeded the capacity of the wrench.

INSPECTION OF BOLTS ON SEPTEMBER 8, 1949

A visual inspection of the bolts at this location revealed that about three-fourths of the bolts had fallen out of the holes and those that remained were so loose that the nuts could be freely turned by hand.

INSTALLATION OF BOLTS ON OCTOBER 22, 1948

The ⅞-in. dia. high-strength bolts were installed at the knee-brace connections, as shown in Sections A–A, A_2–A_2 and A_3–A_3, Fig. 9 and then tightened to the estimated torque with the ratchet wrench as the torque wrench was not available. Final adjustments were made to all the bolts about two weeks later with the torque wrench.

INSPECTION OF BOLTS ON SEPTEMBER 19, 1949

A visual inspection of these bolts indicated that they had retained their clamping force as there was no evidence of rust, cracking of the paint around the bolt or working of the knee-brace on the angle.

The torque wrench was applied to the bolts and none could be found where the nut would start turning at a torque less than 470 ft.-lb. Several of the nuts would not turn when the applied torque equalled the 600 ft.-lb. capacity of the wrench.

A. T. & S. F. Railway System—Bridge 121A at Wilbern, Ill.

The double-track new bridge at Wilbern, Ill., consists of single-track beam spans under the two tracks, as shown in Fig. 10, and were designed for Cooper E72 loading with full AREA impact. Each beam span consists of two 36-in. wide flange beams per rail, having an overall length of 50 ft. The beams are diaphragmed with plates and angles as shown.

INSTALLATION OF BOLTS ON AUGUST 20, 1948

The ⅞-in. dia. bolts were installed in span 1 of the westbound main, see Fig. 10, during the erection of the bridge. Erection bolts had been placed in half of the holes, as the high-strength bolts were not available when this particular span was erected. The high-strength bolts were placed in the remaining holes at each location and tightened to the estimated torque with the ratchet wrench. The erection bolts were then replaced with the high-strength bolts and tightened to the estimated torque.

Several of the bolts in each diaphragm were then checked by marking the position of the nut, backing off the nut and then retightening the bolt with the torque wrench to the required torque. It was not possible to check all the bolts with the torque wrench on account of the limited space between beam flanges, but those checked indicated that the men were applying the required torque with the ratchet wrench.

INSPECTION OF BOLTS ON APRIL 6, 1949

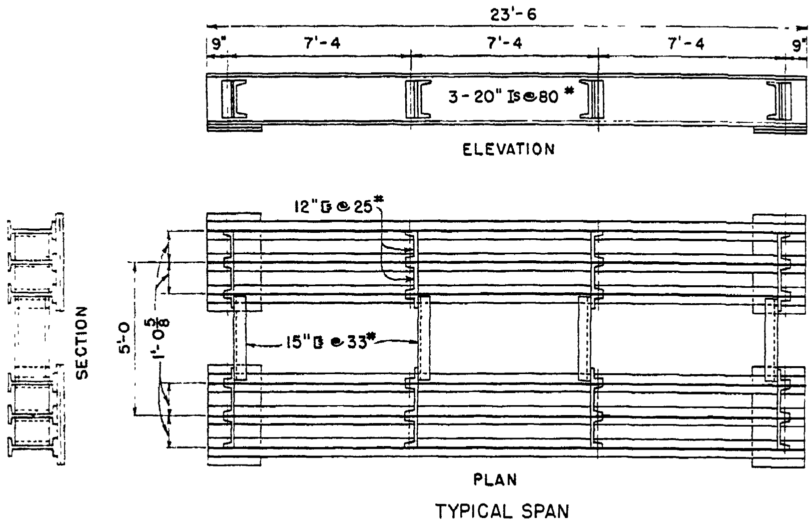
The bolts were first inspected for evidence of cracked paint, rust or slippage of the diaphragm plates on the angles but all bolts appeared to be satisfactory.

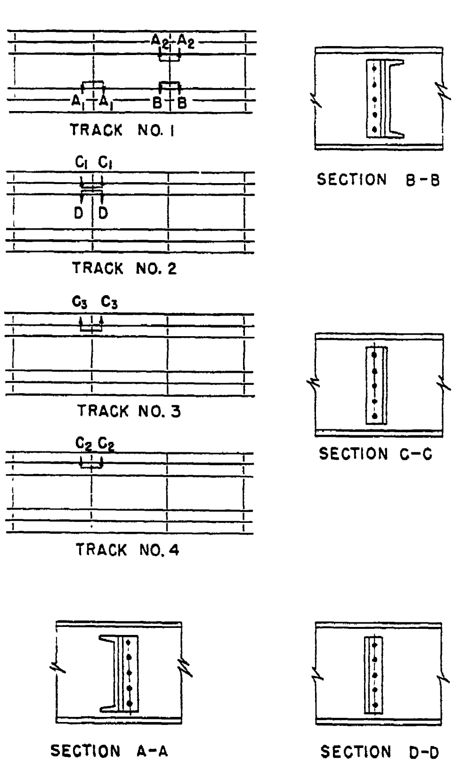
The torque wrench was then applied to several of the accessible bolts in the first line of diaphragms at the east end of the span, see Fig. 10, and most of them started turning at a torque varying from 420 to 450 ft.-lb. as compared to the original torque of 470 ft.-lb. Several of the nuts were marked to show their relative position with the bolts and then backed off a full turn. A torque of from 420 to 450 ft.-lb. was required to bring the nuts back to their original position. The bolts were further tightened to a torque of 470 ft.-lb. and the marks on the nuts at that torque were about 1/16 in. past the original mark.

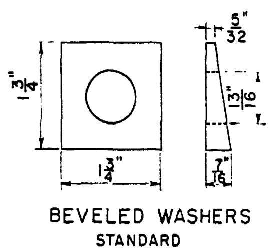
INSPECTION OF BOLTS ON SEPTEMBER 12, 1949

All of the bolts were inspected visually but no evidence of rust, cracked paint or slippage of the diaphragm plate on the angle could be found.

A

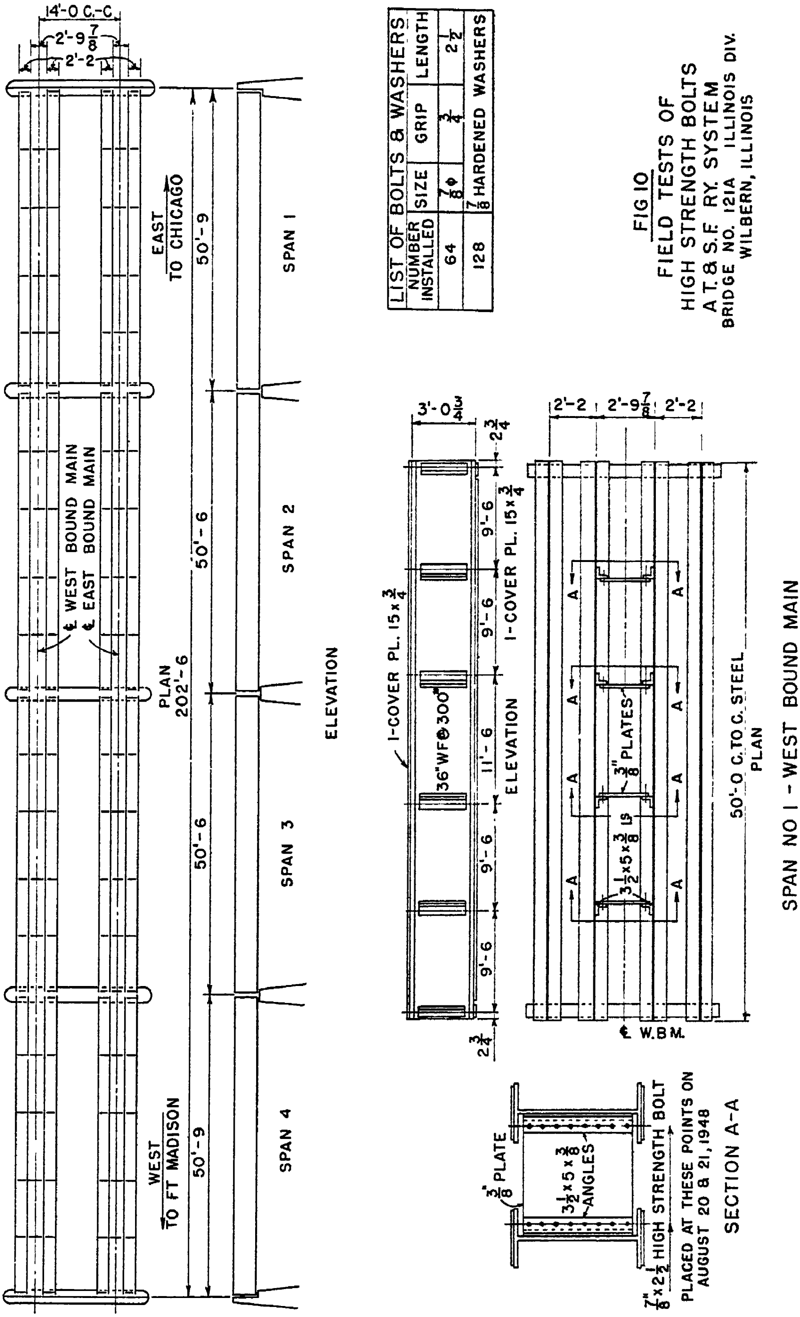






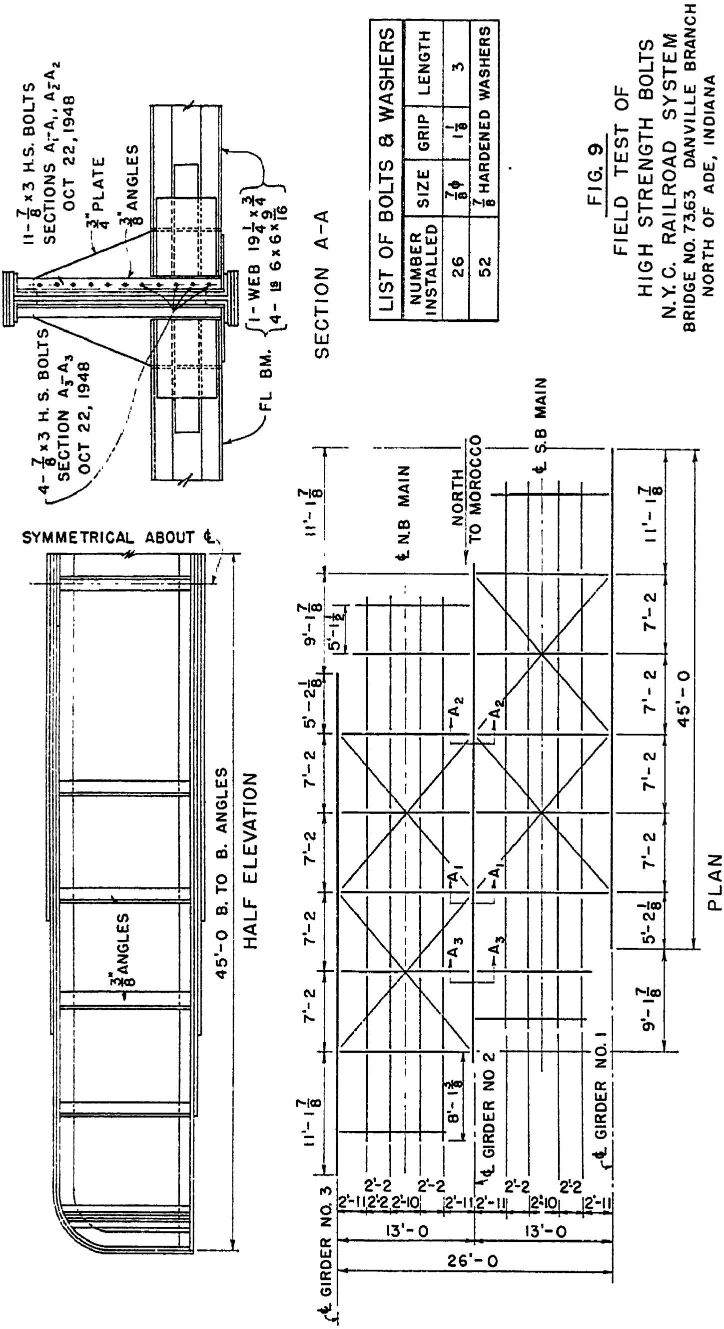
LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
15	$\frac{3}{4}\phi$	$1\frac{5}{8}$	$3\frac{3}{4}$
20	$\frac{3}{4}\phi$	$1\frac{1}{2}$	$3\frac{1}{2}$
70	$\frac{3}{4}$ HARDENED WASHERS		
50	BEVELED WASHERS		

FIG. 8
FIELD TEST OF
HIGH STRENGTH BOLTS
PENNSYLVANIA RAILROAD
BRIDGE NO. 18.58 MARYLAND DIV.
NAAMAN, DELAWARE



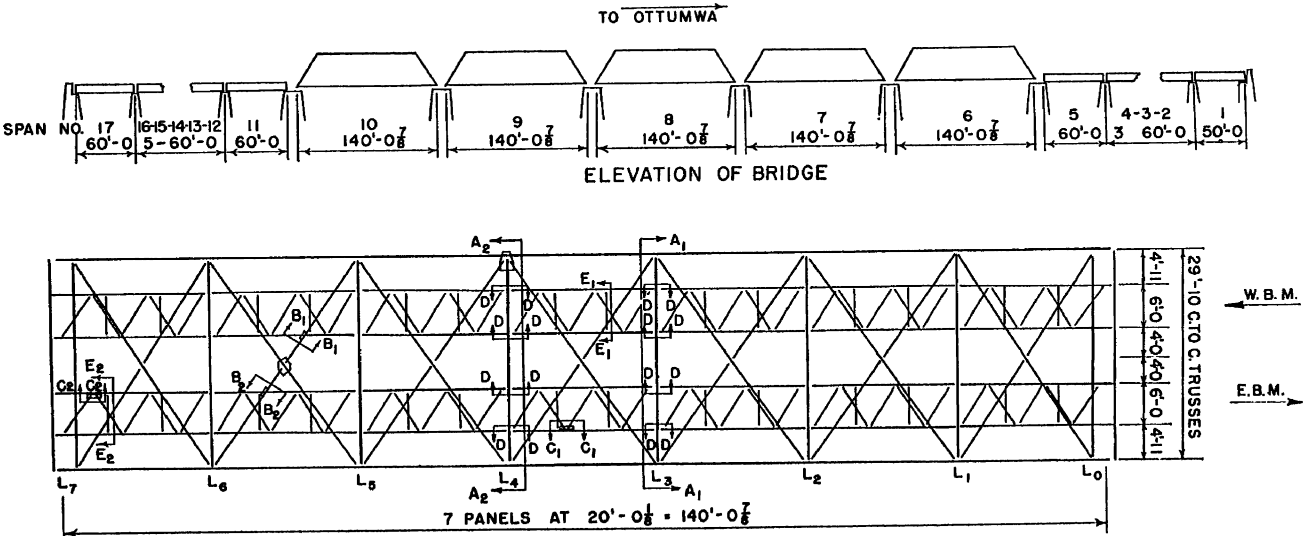
LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
64	$\frac{7}{8}\phi$	$\frac{3}{4}$	$2\frac{1}{2}$
128	$\frac{7}{8}$ HARDENED WASHERS		

FIG 10
FIELD TESTS OF
HIGH STRENGTH BOLTS
A.T. & S.F. RY. SYSTEM
BRIDGE NO. 121A ILLINOIS DIV.
WILBERN, ILLINOIS



LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
26	$\frac{7}{8}\phi$	$1\frac{1}{8}$	3
52	$\frac{7}{8}$ HARDENED WASHERS		

FIG. 9
FIELD TEST OF
HIGH STRENGTH BOLTS
N.Y.C. RAILROAD SYSTEM
BRIDGE NO. 73.63 DANVILLE BRANCH
NORTH OF ADE, INDIANA



PLAN OF SPAN 10

LIST OF BOLTS & WASHERS			
NUMBER	SIZE	GRIP	LENGTH
34	7/8 φ	1 1/2	3 1/4
8	7/8 φ	1	3
12	7/8 φ	15/16	2 3/4
24	7/8 φ	3/4	2 1/2
10	7/8 φ	7/8	2 3/4
24	3/4 φ	3/4	2 1/2
6	3/4 φ	1/4	3
8	BEVELED WASHERS		
176	7/8 HARDENED WASHERS		
60	3/4 HARDENED WASHERS		

FIG. 11
FIELD TEST OF
HIGH STRENGTH BOLTS
C. B. & Q. RAILROAD
BRIDGE NO. 28412 OTTUMWA, DIV.
OTTUMWA, IOWA

Several of the bolts in the first line of diaphragms at the east end of the span were checked with the torque wrench but none of the nuts started turning until a torque greater than 470 ft.-lb. was applied.

The position of the nut on one bolt, selected at random, was marked and the nut then backed off several turns. The bolt was then retightened to a torque of 470 ft.-lb. and the nut returned to its original position with respect to the bolt.

C. B. & Q. Railroad—Bridge 284.12 at Ottumwa, Iowa

The double track bridge at Ottumwa, Iowa, consists of five double-track through truss spans having a length of 140 ft. 7/8 in. center to center of bearings, two single-track deck girder spans with an overall length of 50 ft. and 22 single-track deck girder spans having a length of 60 ft. out to out of steel, as shown on Fig. 11.

The rivets connecting the stringers to the floorbeams and the rivets in the lateral bracing of the truss spans have continuously worked loose, so representative connections in span 10 were selected for the test installations.

Considerable trouble has been encountered in maintaining tight rivets in the lateral bracing of the girder spans, so span 5 was selected as a representative span for these installations.

Installation of Bolts on September 21, 1948

The installation consisted of either burning or knocking off the rivet heads, backing out the rivets and then installing the high-strength bolts and hardened washers. The beveled washers detailed on Fig. 13 were used to compensate for the sloping channel flange in the lateral bracing between the stringers of the truss span.

The rivet heads of the very loose rivets were removed by burning with an acetylene torch and in some locations the metal around the hole was cut away during this burning. The burning of this steel resulted in a very rough irregular bearing surface for the hardened washers which is particularly bad in Section C–C, where the laterals are bolted to the split channel.

Considerable corrosion was found in the stringer flanges at points where the lateral bracing hangers are supported, see Sections B–B and B_2–B_2. In addition to the corrosion, the vibration of the loose rivets in these connections had worn a very rough and irregular bearing surface for the washers. The rust was removed by chipping and the rough flange hammered out as much as possible to improve the bearing surface.

The general procedure in replacing the rivets with the high-strength bolts in the larger lateral bracing connections of this bridge, such as those shown on Fig. 12, was to first replace about half the rivets with bolts to hold the members in place, then the remaining rivets were taken out and the bolts installed. The bolts were then tightened with the ratchet wrench and checked with the torque wrench. The first half of the bolts installed in each joint were heated as the last rivet heads were being cut off and as these bolts were being tightened, the nuts appeared to bind and turned quite hard. To eliminate the heating of the high-strength bolts, the members were held in place by erection bolts until all the rivets had been removed. The high-strength bolts which had been subjected to the heat were left in the stringer lateral connection, Section C–C, and in the stringer cross frame, Section E–E, for future observation.

Inspection of Bolts on September 13, 1949

A visual inspection of all the bolts did not reveal any indication of loose bolts and no movement or slippage of any of the connected members could be detected.

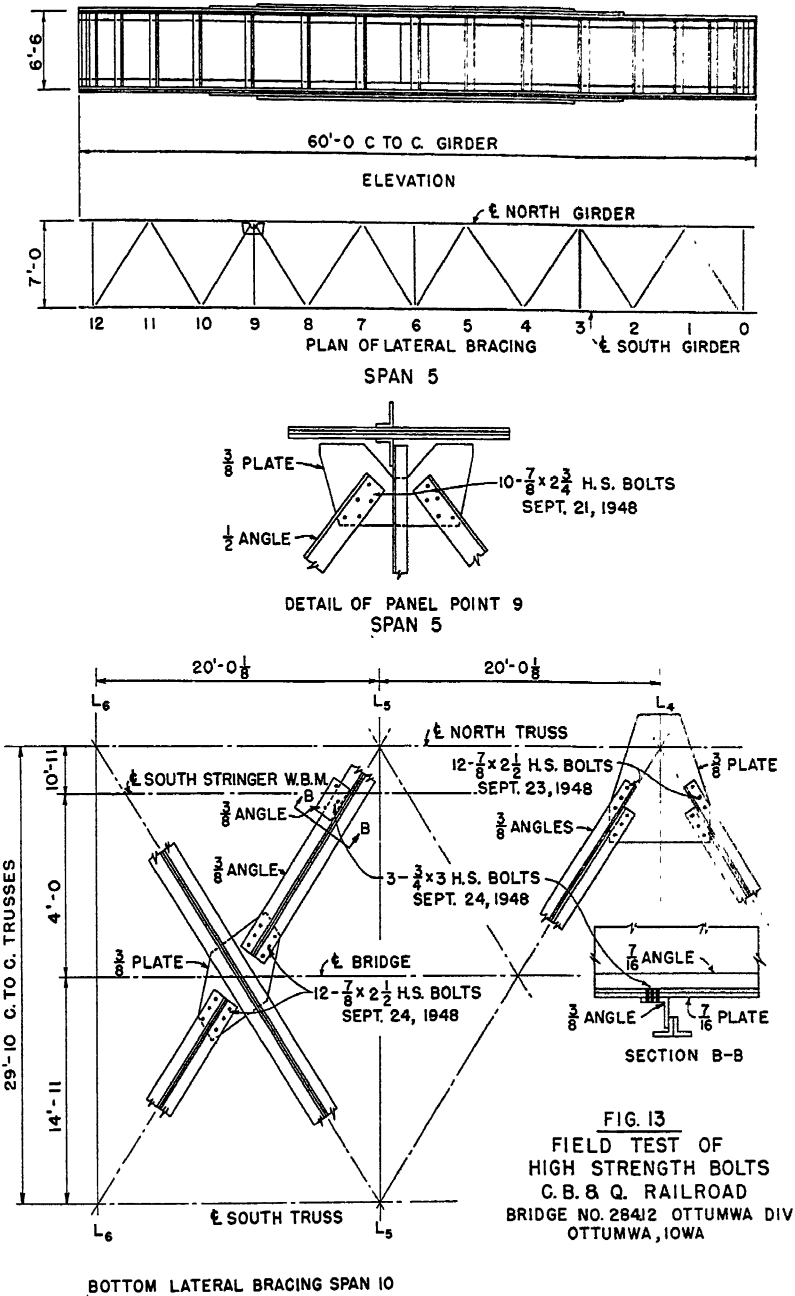


FIG. 13
FIELD TEST OF
HIGH STRENGTH BOLTS
C. B. & Q. RAILROAD
BRIDGE NO. 28412 OTTUMWA DIV
OTTUMWA, IOWA

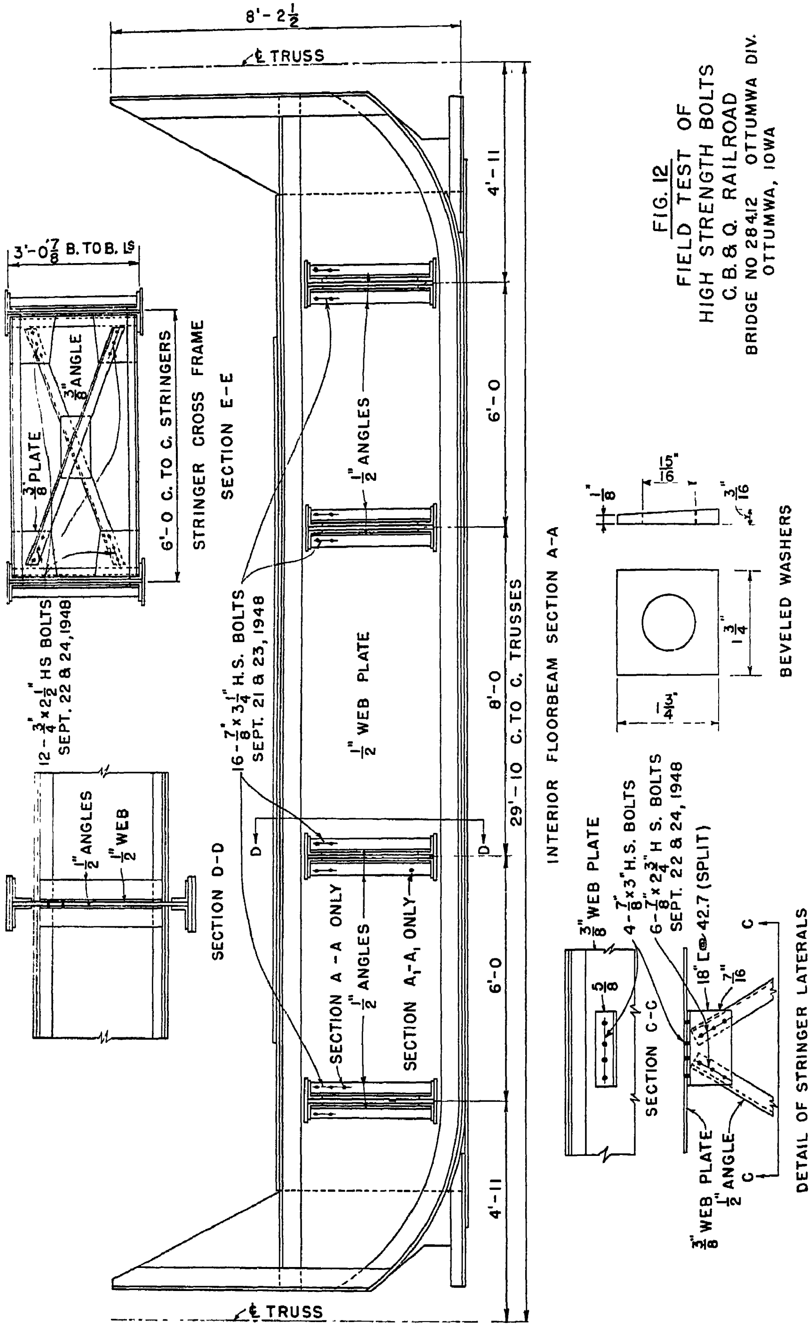


FIG. 12
FIELD TEST OF
HIGH STRENGTH BOLTS
C. B. & Q. RAILROAD
BRIDGE NO 284.12 OTTUMWA DIV.
OTTUMWA, IOWA

Approximately half of the bolts were checked with the torque wrench and the only nuts that would turn, when subjected to the original torque, were those connecting the stringers to the floorbeams, Fig. 12. The nuts on these bolts started tightening at a torque varying from 400 to 440 ft.-lb., as compared to the original torque of 470 ft.-lb. These bolts were retightened to a torque of 480 ft.-lb.

The position of the nut relative to the bolt was marked on several of the ⅞-in. dia. bolts at different connections and the nut then backed off one turn. The bolts were then retightened to a torque of 480 ft.-lb. and in all cases, the nuts returned to their original position.

The bolts connecting the lateral bracing hangers to the lower flanges of the stringers, Sections B–B and B_2–B_2, were checked with the torque wrench but all the bolts were tight.

C. B. & Q. Railroad—Bridge 307.32 at Albia, Iowa

The double track bridge at Albia, Iowa, consists of two single-track through plate girder spans having a length of 90 ft. out to out of girders as shown on Fig. 14.

Installation of Bolts on September 28, 1948

High-strength bolts were installed in the stringer connections and in the lateral bracing connections in a panel close to the center of the span as shown in Figs. 14 and 15. All the bolts were tightened to a torque of 470 ft.-lb. as measured by the torque wrench, except the top bolts in the stringer connections to the end floorbeam. These top bolts were tightened with the ratchet wrench to the approximate torque.

Inspection of Bolts on September 13, 1949

About half the bolts were checked with the torque wrench after a visual inspection did not indicate any loose bolts. None of the nuts would turn when subjected to the original torque.

C. & N. W. Railway—Bridge 711 at Beaver, Iowa

The double-track bridge at Beaver, Iowa, consists of four single-track deck girder spans having a length of 60 ft. out to out of girders.

The rivets connecting the cross frames to the stiffener angles on the girders, as shown on Fig. 16, had become loose and had been replaced with standard bolts and spring washers. The standard bolts became loose within a year but the spring washers had retained sufficient pressure to prevent the nuts from backing entirely off of the bolt.

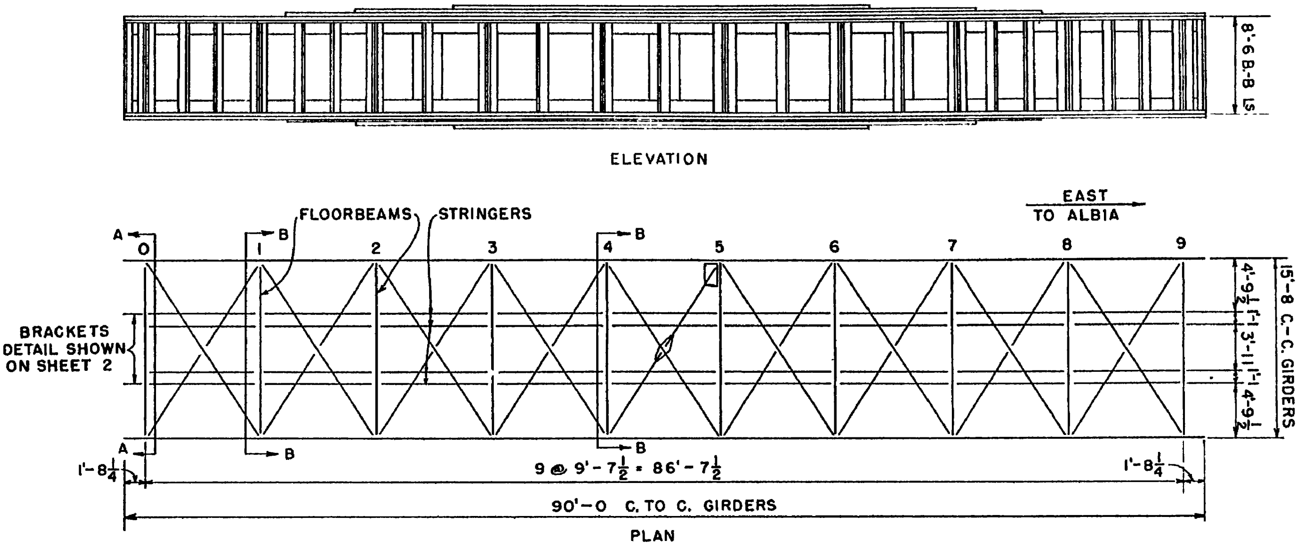
Installation of Bolts on November 3, 1948

The standard washers were replaced with high-strength bolts and hardened washers and then tightened to a torque of 470 ft.-lb. as measured by the torque wrench.

Inspection of Bolts on September 14, 1949

The bolts were inspected for cracked paint, rust or slippage of the plates on the stiffener angles but all bolts appeared to be tight.

The torque wrench was then used to check the bolts and it was generally found that the nuts on two of the bolts at each connection would move at a torque slightly below the tightening torque of 470 ft.-lb., while the nut on the third bolt required a greater applied torque before turning. It is quite possible that this difference in torque results from not tightening the bolts the second time when they were installed, as the tightening of the last bolt could relieve the clamping force in the other two bolts.



SPAN NO. 1 WEST BOUND MAIN

LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
7	$\frac{7}{8}\phi$	$\frac{7}{8}$	$2\frac{3}{4}$
11	$\frac{7}{8}\phi$	1	$2\frac{3}{4}$
28	$\frac{7}{8}\phi$	$1\frac{1}{2}$	$3\frac{1}{4}$
92	$\frac{7}{8}$ HARDENED WASHERS		

FIG. 14
FIELD TEST OF
HIGH STRENGTH BOLTS
C. B. & Q. RAILROAD
BRIDGE NO. 307.32 OTTUMWA DIV.
ALBIA, IOWA

The position of the nut relative to the bolt was marked on one of the bolts that appeared tight and the nut then backed off one full turn. The bolt was then tightened to a torque of 480 ft.-lb. and the nut returned to its original position.

All of the bolts which started tightening at a torque below 480 ft.-lb. were retightened with the torque wrench.

C. M. St. P. & P. Railroad—Bridge Z312 at Byron, Ill.

The double-track bridge at Byron, Ill., consists of five 160-ft. single-track through truss spans of modern design in the eastbound track and five 160-ft. single-track through truss spans of lighter design in the westbound track, see Fig. 17.

Considerable trouble has been encountered in keeping the rivets tight in the top and bottom lateral systems of the truss spans in the westbound track and it has been necessary to periodically redrive a considerable number of these rivets.

All the rivets in the top and bottom lateral bracing of the truss spans in the westbound span were inspected and all loose rivets were marked. Arrangements were then made to replace all the loose rivets with high-strength bolts.

Installation of Bolts on November 15, 1949

The loose rivets at all the locations shown on Figs. 17, 18 and 19 were replaced by ⅞-in. dia. high-strength bolts and the bolts then tightened to develop a stress equal to 85 percent of the yield strength of the steel.

The bolts in spans 1 and 5 were tightened with a ratchet wrench to the approximate torque of 470 ft.-lb. and then a few bolts were selected at random for checking with the torque wrench. On spans 2, 3 and 4, an air powered impact wrench was used in place of the ratchet wrench to tighten the bolts. The impact wrench was capable of exceeding the required torque if held on the nut long enough, but after experimenting on several bolts and checking the tightness with the torque wrench, the operator was consistently able to tighten the bolts to the required torque. A check on the tightness of the bolts was maintained by selecting bolts at random in each joint, except those in the top lateral system, for testing with the torque wrench. The bolts in the top lateral system were tightened to the approximate torque with either the ratchet wrench or the impact wrench without a check by the torque wrench.

Inspection of Bolts on September 15, 1949

All of the bolts were inspected visually but no evidence of rust, cracked paint or slippage of the members could be found.

The bolts on the outside of the stringers and those inside the stringers at the piers were checked with the torque wrench and it was found that the nuts on these bolts usually started turning at a torque slightly below that which was used on the bolts when they were installed. The torque at which the nuts started turning varied from a low of 280 ft.-lb. to 480 ft.-lb., with an average of about 400 ft.-lb. The loss of clamping force may be the result of a re-seating of the members or a result of not tightening the bolts to the required torque of 470 ft.-lb. during the installation of the bolts. The bolts were only spot checked with the torque wrench when installed and no record was kept of those that were checked.

All of the bolts that started turning at a torque smaller than 470 ft.-lb. were retightened with the torque wrench and identified for future reference.

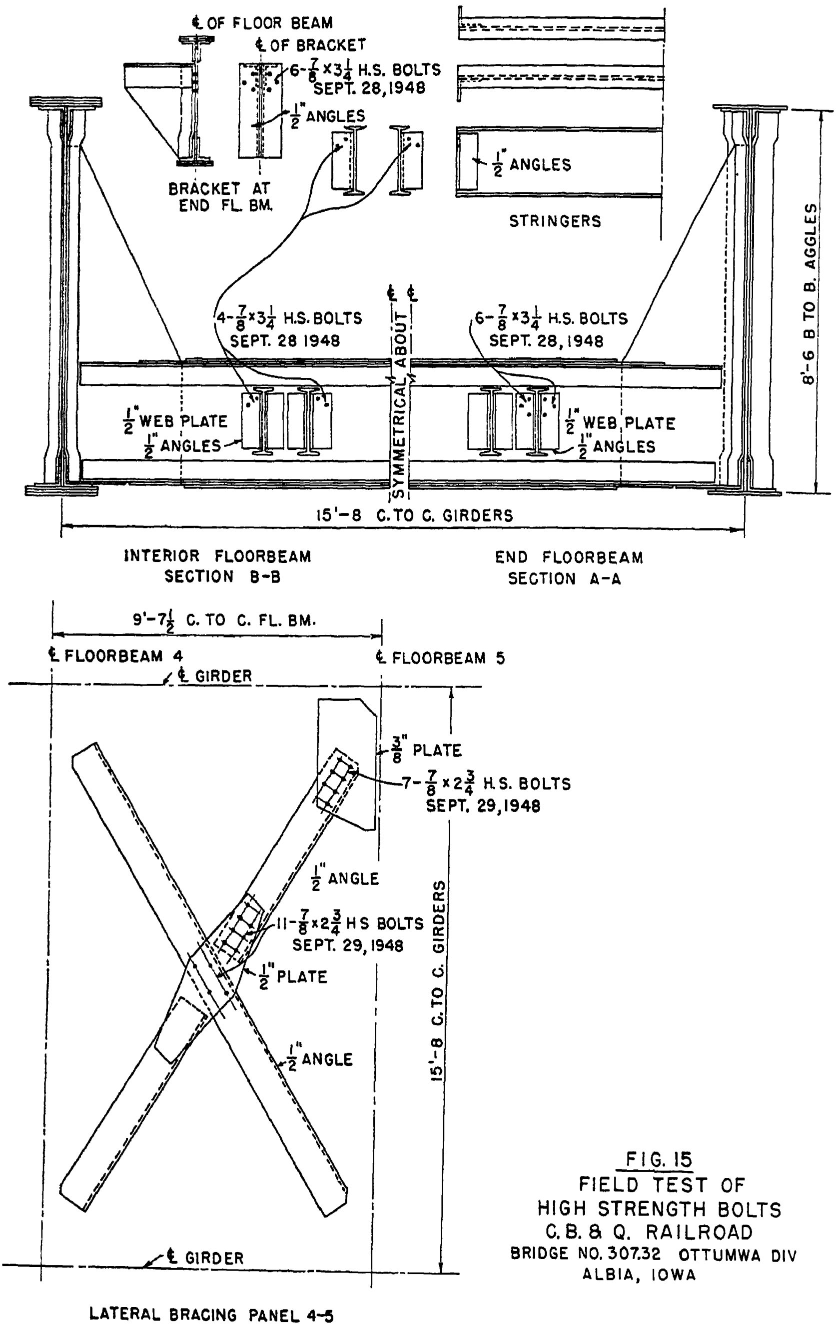
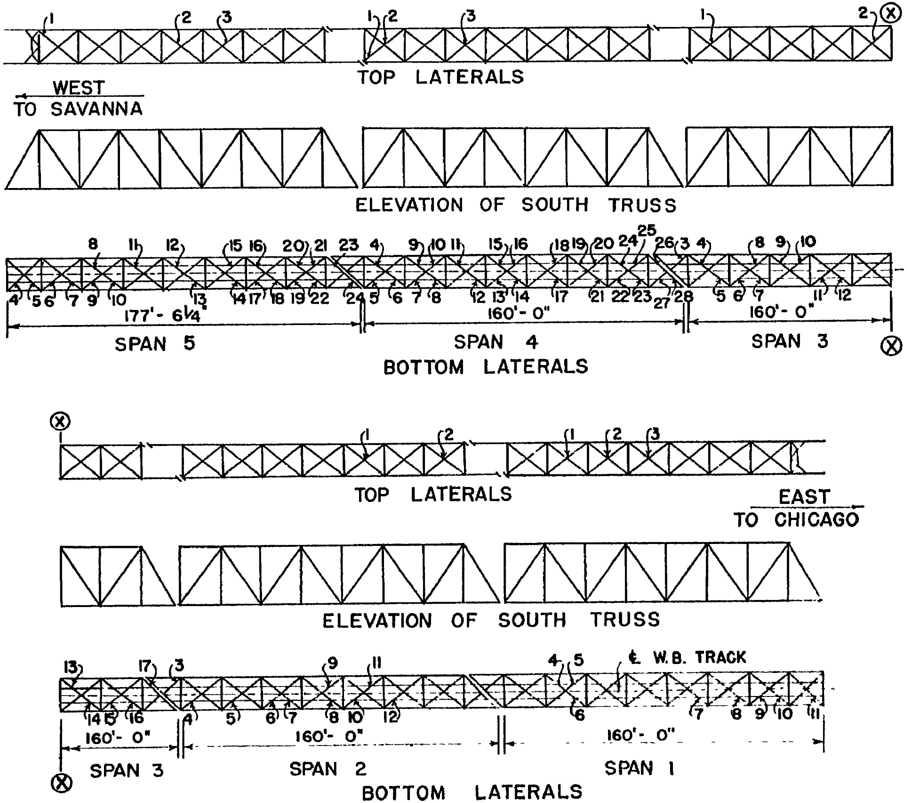
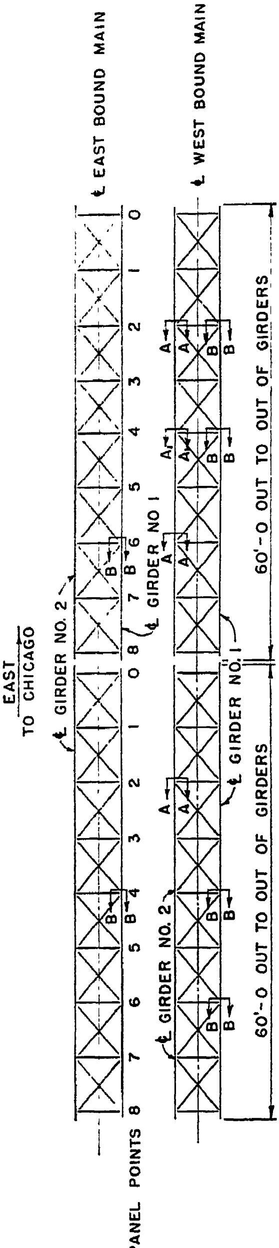


FIG. 15
FIELD TEST OF
HIGH STRENGTH BOLTS
C. B. & Q. RAILROAD
BRIDGE NO. 307.32 OTTUMWA DIV
ALBIA, IOWA



LIST OF BOLTS & WASHERS			
NUMBER	SIZE	GRIP	LENGTH
43	$\frac{7}{8}\phi$	$\frac{3}{4}$	$2\frac{1}{2}$
142	$\frac{7}{8}\phi$	$1\frac{1}{16}$	$2\frac{3}{4}$
46	$\frac{7}{8}\phi$	$1\frac{7}{16}$	$3\frac{1}{4}$
462	$\frac{7}{8}$ HARDENED WASHERS		

FIG. 17
FIELD TEST OF
HIGH STRENGTH BOLTS
C. M. ST. P. & P. R.R.
BRIDGE NO Z-312 ROCK RIVER BRIDGE
BYRON , ILLINOIS



LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
20	$\frac{7}{8}\phi$	$\frac{3}{4}$	$2\frac{1}{2}$
10	$\frac{7}{8}\phi$	$1\frac{1}{8}$	$2\frac{3}{4}$
60	$\frac{7}{8}$ HARDENED WASHERS		

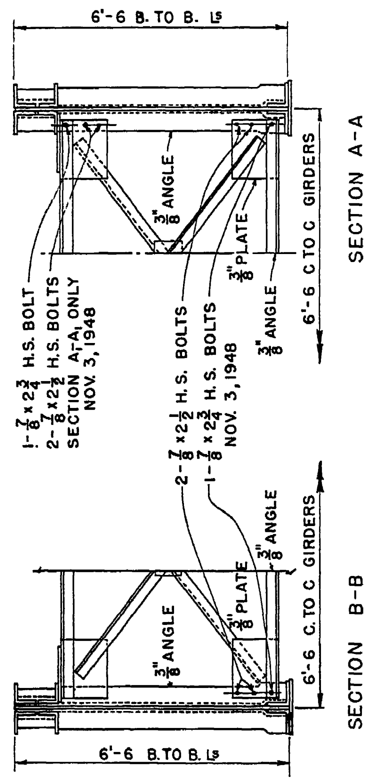


FIG. 16
FIELD TEST OF
HIGH STRENGTH BOLTS
C. & N. W. RAILWAY
BRIDGE NO. 711 IOWA DIVISION
BEAVER, IOWA

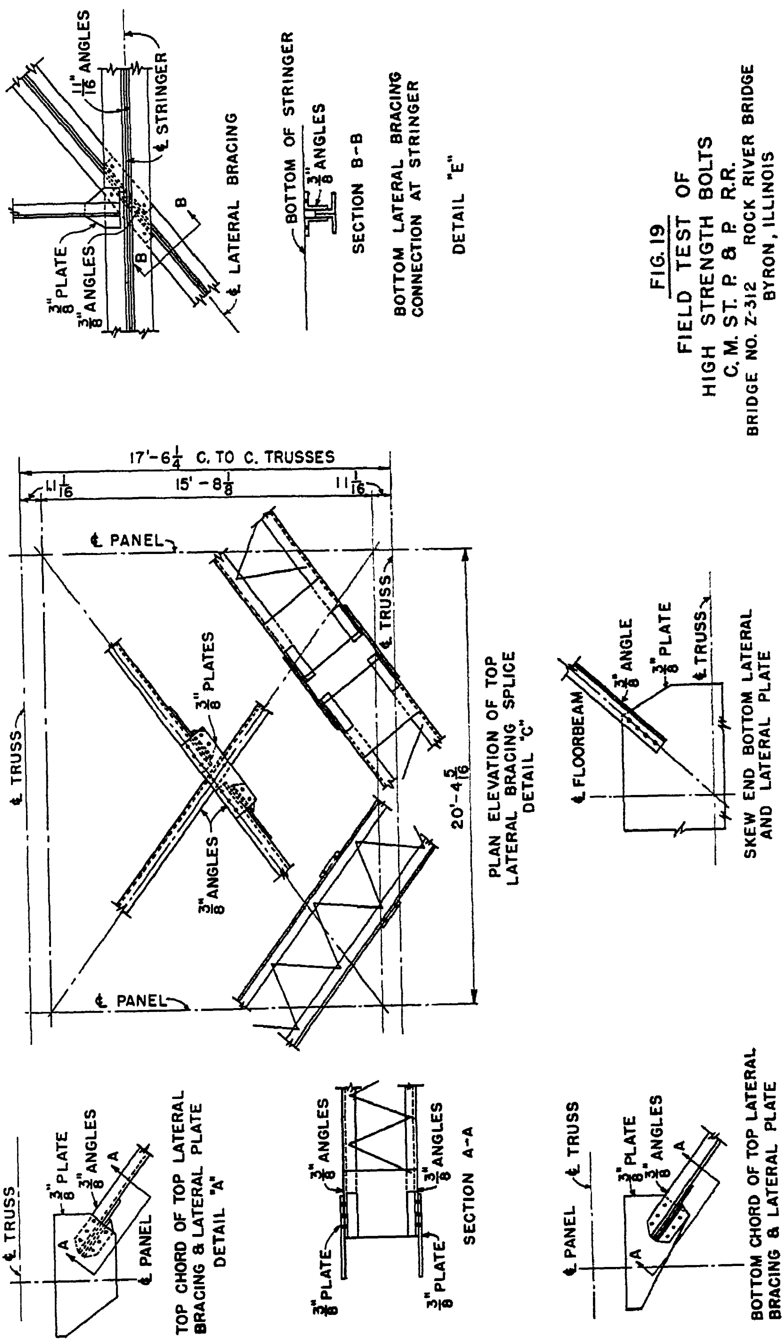


FIG. 19
FIELD TEST OF
HIGH STRENGTH BOLTS
C. M. ST. P. & P. R.R.
BRIDGE NO. Z-312 ROCK RIVER BRIDGE
BYRON, ILLINOIS

LOCATION OF BOLTS

SPAN	LOCATION	NO. OF BOLTS LENGTH 2½	2¾	3¼	DETAIL	REMARKS
1	1	4			C	2-TOP-2 BOT.-INTERSECT.
	2	2			C	BOTT INTERSECTION
	3	4			C	2-TOP-2BOT.-INTERSECT.
	4		2		E	
	5			1	E	
	6		3	1	E	
	7		1		E	
	8		3	1	E	
	9		3	1	E	
	10		1		E	
	11		1		E	
2	1	4			C	2TOP-2BOT.-INTERSECT.
	2	4			C	" " "
	3	2			D	
	4		1		E	
	5		2		E	
	6		1		E	
	7		1		E	
	8		3	1	E	
	9		3	1	E	
	10		2		E	
	11		1	1	E	
	12		2	1	E	
3	1	1			C	TOP SPLICE PLATE
	2	4			C	2TOP-2 BOT-INTERSECT.
	3	3			D	
	4		1		E	
	5		3	1	E	
	6		2	1	E	
	7		2		E	
	8		2		E	
	9		1		E	
	10		3	1	E	
	11		3	1	E	
	12			1	E	
	13		1		E	
	14		3	1	E	
	15		3	1	E	
	16		3	1	E	
	17		3	1	E	

SPAN	LOCATION	NO. OF BOLTS LENGTH 2½	2¾	3¼	DETAIL	REMARKS
4	1	2			A&B	1-TOP, 1-BOTT.
	2	4			C	2TOP-2 BOTT-INTERSE
	3	4			C	" " "
	4		3	1	E	
	5		3	1	E	
	6		3	1	E	
	7		2		E	
	8		3	1	E	
	9		3	1	E	
	10		1		E	
	11		1	1	E	
	12		2	1	E	
	13		2		E	
	14		3	1	E	
	15			1	E	
	16		3	1	E	
	17		1		E	
	18			1	E	
	19		3	1	E	
	20		3	1	E	
	21		2		E	
	22		3	1	E	
	23		3	1	E	
	24		3	1	E	
	25		3	1	E	
	26		3	1	E	
	27		1	1	E	
	28		2		E	

SPAN	LOCATION	NO. OF BOLTS LENGTH 2½	2¾	3¼	DETAIL	REMARKS
5	1	1			A	
	2	3			C	2 TOP 1 BOT. INTERSECT
	3	1			C	TOP SPLICE PLATE
	4		1		E	
	5		1		E	
	6		1		E	
	7		1		E	
	8		3	1	E	
	9		1		E	
	10			1	E	
	11		1		E	
	12		1		E	
	13		1		E	
	14		1		E	
	15		1		E	
	16		1	1	E	
	17		1	1	E	
	18		1		E	
	19		1	1	E	
	20		3	1	E	
	21		3	1	E	
	22		1		E	
	23		3	1	E	
	24		1	1	E	

FIG 18
FIELD TEST OF
HIGH STRENGTH BOLTS
C. M. ST. P. & P. RR.
BRIDGE NO. Z-312 ROCK RIVER BRIDGE
BYRON, ILLINOIS

Southern Railway System—Bridge 151.4 at Mt. Carmel, Ill.

The single track bridge at Mt. Carmel, Ill., spans the Wabash river and consists of five through pin-connected truss spans and one pin-connected through draw span. The bridge was built in 1886 and was designed for light loads.

A crack was found in the north floorbeam hanger channel at the east end of span 3 during June 1948. The crack in the failed hanger was burned out and successfully welded shortly after the failure was found.

It appears that the failure in the hanger, which started at the cope in the channel flange, was a fatigue failure resulting from the high stress raiser produced by the cope. Material was immediately ordered to strengthen all the hangers in this bridge by bolting the reinforcing plates to the channel webs as shown in Fig. 20.

Installation of Bolts on October 5, 1948

The four rivets connecting the pin plates to the channels were removed and the reinforcing plates were then bolted to the outside of the channels with ⅞-in. dia. high-strength bolts. The reinforcing plates were then used as jigs to drill the four lower holes in the channels. The remaining bolts were then installed and all bolts tightened to a torque of 470 ft.-lb.

The majority of the bolts were tightened by means of a ratchet wrench with a three-foot extension as the torque wrench could not be left at the bridge for the complete installation.

Inspection of Bolts on September 27, 1949

The bolts at each location were thoroughly examined for signs of rust, cracked paint or slippage of the members but no such evidence could be found.

The accessible bolts at the two hangers of each truss were checked with the torque wrench and found to be tight. However, only 10 of the 16 bolts at each hanger were accessible for checking with the torque wrench without removing the lattice bars and the batten plates. The bars were removed from one hanger and all the bolts checked at this one location but no loose bolts could be located.

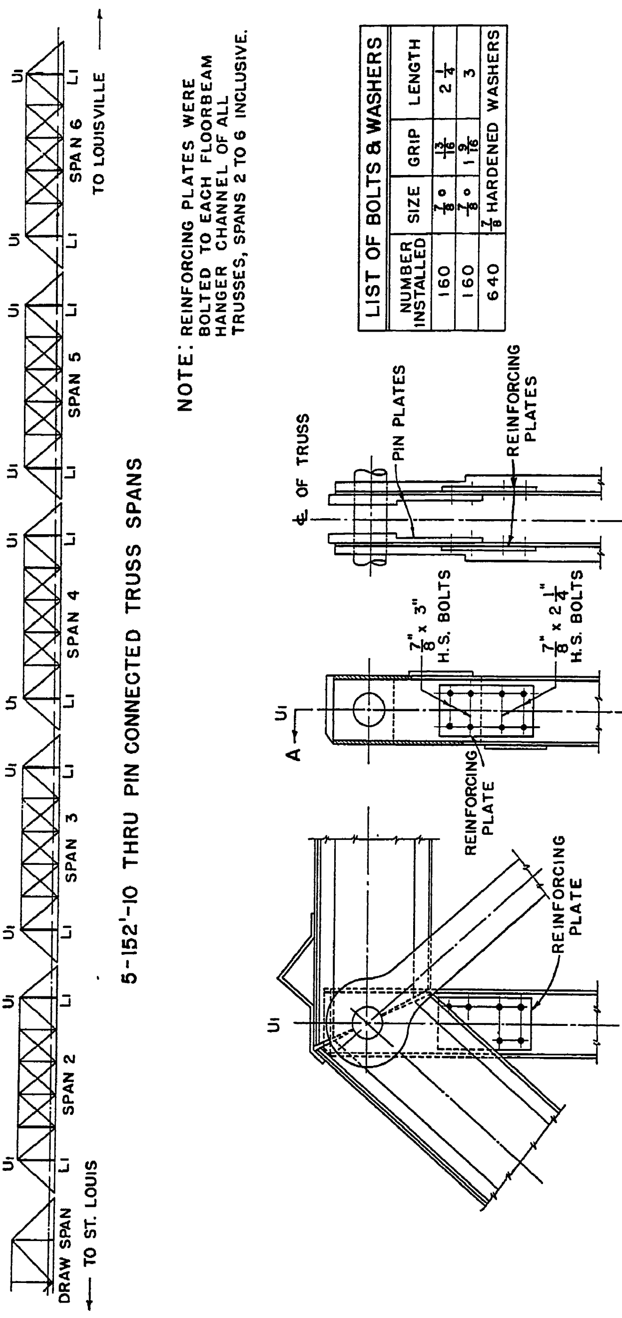
On several bolts the position of the nut relative to the bolt head was marked and the nut then backed off one full turn. These nuts started backing off at a torque of about 560 ft.-lb. The bolts were then retightened to a torque of 480 ft.-lb. and the nuts returned to their original position.

6. Conclusions

The installation of high-strength bolts in structural joints of bridges carrying moving loads has afforded an opportunity to compare their behavior with the past behavior of rivets in the same holes and also a comparison with the behavior of new rivets in similar joints.

The behavior of high-strength bolts and hardened washers, purchased in compliance with the previously stated specifications, has been very satisfactory during a service period of over a year and it seems logical to make the following conclusions from a study of these test installations:

1. To avoid the breakage of the bolts subjected to high bending stresses it appears that the bolts should have fillets at the junction of the head and shank.
2. Bolts should not be installed in enlarged or irregular shaped holes without providing proper bearing surface for the hardened washers.
3. All the bolts in a joint should first be tightened to the approximate torque and then each individual bolt again checked for the proper torque.



LIST OF BOLTS & WASHERS			
NUMBER INSTALLED	SIZE	GRIP	LENGTH
160	$\frac{7}{8}$ °	$\frac{13}{16}$	$2\frac{1}{4}$
160	$\frac{7}{8}$ °	$1\frac{9}{16}$	3
640	$\frac{7}{8}$ HARDENED WASHERS		

FIG. 20
FIELD TEST OF HIGH STRENGTH BOLTS
SOUTHERN RAILWAY SYSTEM
BRIDGE NO. 151.4 WABASH RIVER BRIDGE
MT CARMEL, ILLINOIS

Report of Committee 4—Rail

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BARTON WHEELWRIGHT
R. P. WINTON
J. E. YEWELL
Committee

* Died December 7, 1949.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

AREA Bulletin 486, February 1950.

A

4. High-strength bolts properly installed stayed tight longer than rivets in similar joints subjected to the same vibrational loads.

5. High-strength bolts have a definite use in the maintenance work of railroad bridges.

7. Acknowledgement

The Committee on Iron and Steel Structures and the American Railway Engineering Association are indebted to the various railroads for their cooperation in making these test installations.

A canvass is being conducted by a special subcommittee on the viewpoint of the railroads on the adoption of a greater length for steel rails.

Report on Assignment 2

Conditions Affecting Service Life of Rail, Causes of Rail Failures and Other Defects

In Collaboration with AISI Technical Committee on Rail and Joint Bars

Ray McBrian (chairman, subcommittee), C. B. Bronson, E. E. Chapman, H. R. Clarke, C. J. Code, L. S. Crane, J. L. Gressitt, L. T. Nuckols, R. P. Winton.

A progress report on the rails investigation, comprising a cooperative project conducted at the Engineering Experiment Station of the University of Illinois, the expense of which is borne jointly by the Association of American Railroads and the American Iron & Steel Institute Technical Committee on Rails and Joint Bars is presented below:

Appendix 2–a

Investigation of Failures in Railroad Rails

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

This investigation is financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Student assistants H. L. Smith and D. R. Yeager have worked on this investigation during the past year.

Examination of Control Cooled Rails Which Failed in Service

Twenty-four failed control cooled rails were sent to the laboratory by the engineers of 12 railroads. Reports were written on these rails for these engineers, the rail manufacturers and the engineer of tests of the AAR.

Table 1 gives a summary of these failures, while Table 2 lists each rail separately.

Table 1.—Summary of Failures in Control Cooled Rails

Transverse fissures from hot torn steel	7
Transverse fissure from shatter crack	1
Detail fracture from shelling	3
Detail facture from head checks	2
Compound fissures from welded engine burns	3
Compound fissure from hot torn steel	1
Gage corner shelling	2
Fracture from broken base	1
Lap on rail head	1
Engine burn fracture	1
Bolt hole failure	1
Head and web separation	1
Total	24

The Committee on Rail,
Ray McBrian, *Chairman*.

Robert Franklin Logan

The committee records with regret the death on December 7, 1949 of Robert F. Logan, who was serving his first year as one of its members. He was born at Yadkinville, N. C., on March 13, 1904 and following graduation in civil engineering from the University of North Carolina, he entered the service of the Southern Railway as a student engineer in November 1925, advancing through various positions in the maintenance of way and transportation departments of the Southern. He was promoted to division superintendent in June 1941 and to chief engineer maintenance of way and structures of the central lines at Knoxville, Tenn. in December 1947, occupying the latter position at the time of his death. He became a member of the Association in April 1948.

Report on Assignment 1

Revision of Manual

C. J. Code (chairman, subcommittee), J. E. Armstrong, C. H. Blackman, W. J. Burton, J. L. Gressitt, R. L. Groover, G. F. Hand, C. C. Lathey, R. F. Logan, R. R. Manion, Ray McBrian, R. J. Middleton, L. T. Nuckols, E. E. Oviatt, R. E. Patterson, E. F. Salisbury, A. A. Shillander, G. L. Smith, H. F. Whitmore, Barton Wheelwright.

This is a progress report presented as information. There are no revisions of Manual material under the jurisdiction of the Rail Committee to be presented for consideration this year.

During the year a canvass was conducted of the various methods in use on the railroads for handling the matter of X rayls. This developed a variety of viewpoints and a suggested revision of paragraph 303 of the Specification for Open-Hearth Steel Rails. This proposed revision is being given further study by the subcommittee before making a definite recommendation.

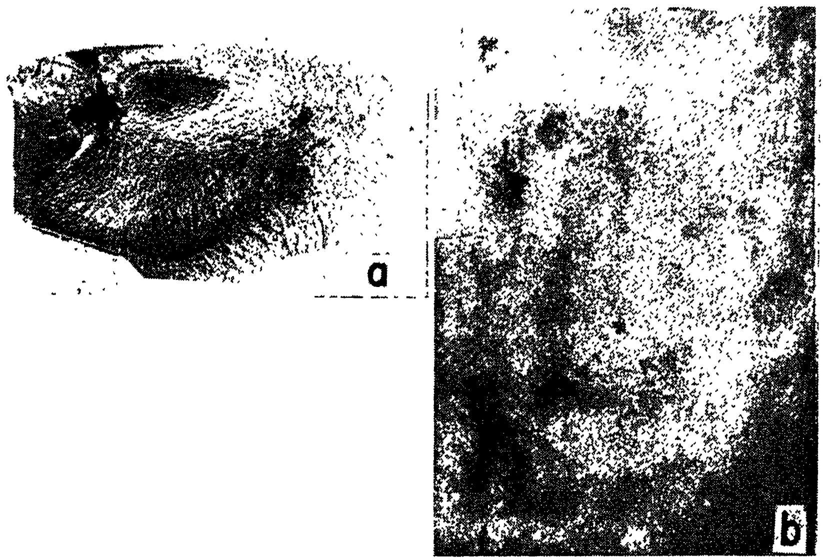


Fig. 1.—Transverse Fissure from Hot Torn Steel.

(a) Fracture with 75-percent fissure developed from hot torn hole.
(b) Etched slice showing hot torn holes. Etched in hot 50-percent hydrochloric acid.

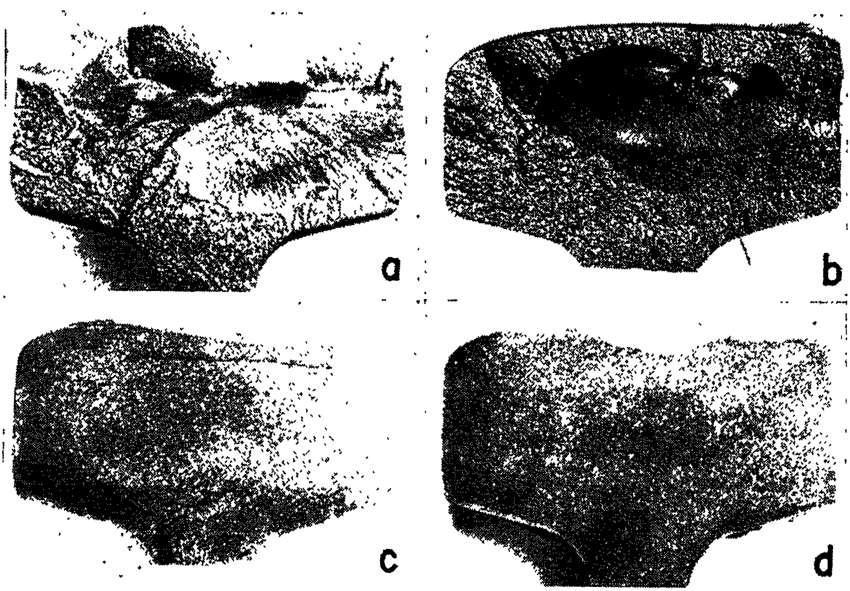


Fig. 2.—Two Compound Fissures from Welded Engine Burns.

(a) and (b) Compound fissures as received.
(c) and (d) Etched slices showing areas built up by welding on rail treads. Etched in hot 50-percent hydrochloric acid.

TABLE 2.—FAILED CONTROL COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1948 AND OCTOBER 1, 1949

D. F. = Detailed Fracture; T. F. = Transverse Fissure; C. F. = Compound Fissure

Source of Failed Rail	*Laboratory Failed Rail No.*	*Size of Rail*	*Mill*	*Heat No. Rail Letter and Ingot*	*Date Rolled*	*Classification of Failure*
M.P.	591	112	Gary	56410–A–10	8–1937	D.F. from shelling
C.N.	592	100	Dominion	A753–D–16	1–1948	Fracture from broken base
Virginian	593	131	Steelton	84450–B–6	10–1940	T.F. from hot torn steel
B. & O.	594	131	Steelton	82614–B–4	12–1944	C.F. from hot torn steel
C. of G.	601	112	Ensley	877317–E–6	4–1943	Gage corner shelling
C. of G.	602	112	Ensley	887031–G–12	4–1943	Gage corner shelling
Santa Fe	603	112	Steelton	86040–F–3	1–1937	T.F. from hot torn steel
Santa Fe	604	112	Steelton	82028–D–9	1–1937	T.F. from hot torn steel
Santa Fe	605	131	Inland	32418–D–17	4–1941	T.F. from hot torn steel
C. of G.	606	112	Ensley	870943–E	10–1946	D.F. from head checks
C. of G.	607.	90	Ensley	851063–G	12–1936	D.F. from shelling
Erie	608	131	E.Thomson	208175–B–27	4–1940	C.F. from welded engine burn
Erie	609	131	E.Thomson	208175–B–28	4–1940	C.F. from welded engine burn
W. & L. E.	610	110	E.Thomson	04H163–B–21	4–1947	Bolt hole failure
N. Y. C.	611	127				Head and web separation
S. P.	612	113	Colorado	10096–D	1946	D.F. from head checks
B. & O.	613	131	E.Thomson	208285–C–1	6–1941	D.F. from shelling
W. & LE.	614	110	E.Thomson	207095–E–16	4–1936	C.F. from electric weld
N. Y. C.	615	127	Lackawanna	13495–D–18	8–1944	T.F. from hot torn steel
Wabash	616	112	Gary	47390–E–1	1937	T.F. from shatter crack
S. P.	617	131	Steelton	84324–E–14	1939	T.F. from hot torn steel
S. P.	618	112	Steelton	83338–C–16	1939	T.F. from hot torn steel
Wabash	619	115	Inland	27584–H–18	11–1948	Lap on rail head
C. P. R.	620	100	Algoma	2036–B–9	1–1937	Engine burn fracture

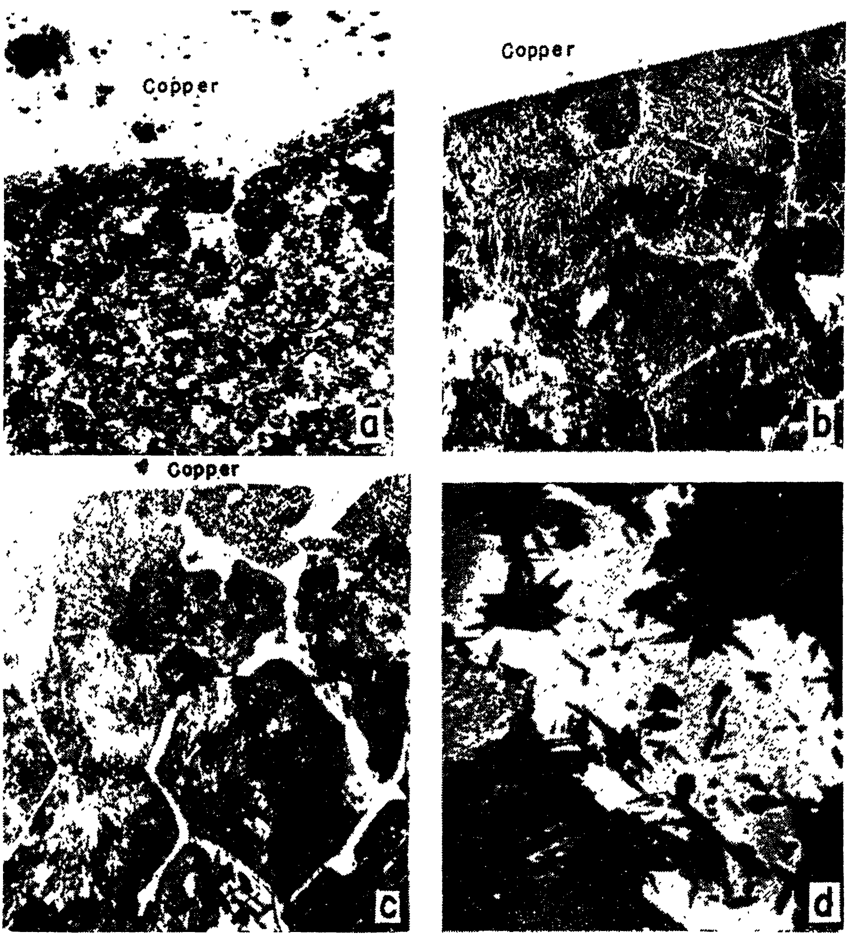


Fig. 4.—Metallographic Tests of Torch Welded Bonds, All Specimens Etched with 2-Percent Nital.

(a) Junction of copper and rail. 100× Mag.
(b) Another junction area. 600× Mag.
(c) Copper penetration at grain boundaries of rail steel. 600× Mag.
(d) Small martensite area. 600× Mag.

Preliminary Tests of Rails with Welded Bond Wires

The question of possible damage to rails by welding bond wires on the field side of the rail head has been raised by several railroad engineers and a few preliminary tests have been made. Two methods of bond wire welding were used to prepare the specimens; the free held acetylene torch and the thermit welding methods. Fig. 3a shows

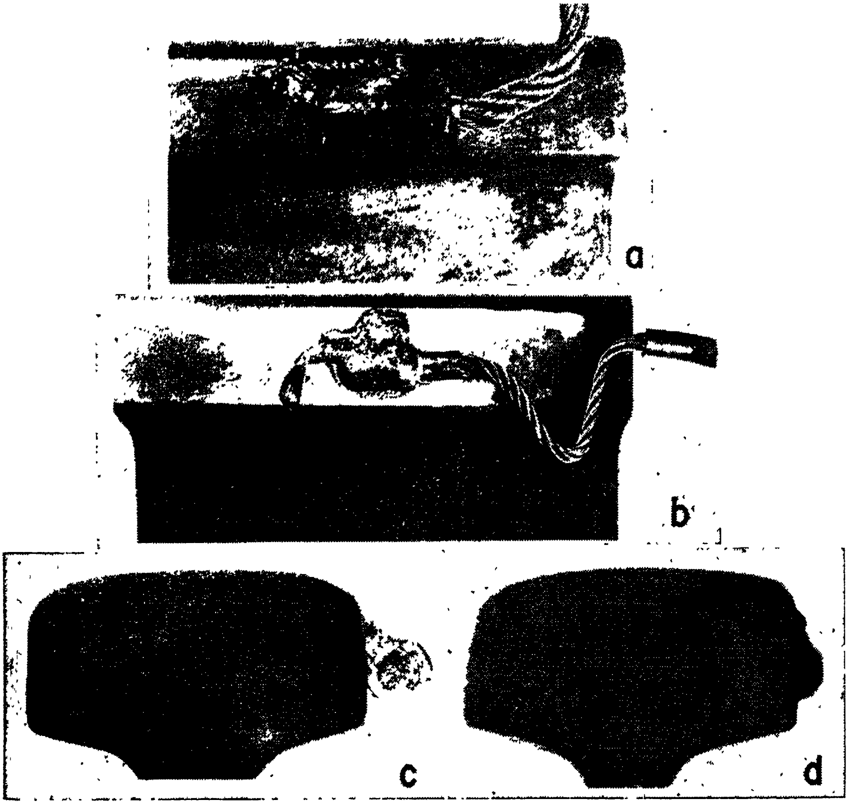


Fig. 3.—Bond Wires Applied by Welding Torch and Thermit Welding.

(a) Free held acetylene torch. (b) Thermit welding.

(c) Cross section of torch welded bond wire.

(d) Cross section of thermit welded bond wire.

Specimens (c) and (d) etched with ammonium persulfate.

Note.—Heated zones are etched black.

It will be noted from Table 1 that there was only one rail which developed a transverse fissure from shatter cracks and it was rolled in 1937 before the mill cooling container lids had been insulated. The number of failures from hot torn steel, see Fig. 1, has declined to ⅓ of the number found last year, which is very encouraging, and none of these was found in rails rolled since 1945.

Fig. 2 shows two compound fissures from welded engine burns. The horizontal cracks in both of these rails grew to a length of two or three inches before taking a transverse direction so that the fractures were not directly under the welded areas. The etched sections show that the rails had been built up by welding at engine burns.

Metallographic Tests of Torch Welded Rail Bonds

Fig. 4 shows four photomicrographs of the torch welded rail. Fig. 4a is at 100× magnification at the junction of the copper and steel. The steel shows a fine grain structure in the heated area. Fig. 4b shows a similar area at 600× magnification. Fig. 4c shows another area at 600× magnification where the copper has penetrated around the steel grains during the welding. Fig. 4d is an isolated martensite grain about ⅛ in. away from the junction of the copper and steel. Only a few martensite grains were found and they were tested for hardness using the Vickers diamond Brinell test. These martensite grains gave hardness readings above 600 standard Brinell hardness.

Metallographic Tests of Thermit Welded Rail Bond

Fig. 5a shows a photomicrograph of the thermit welded bond at 100× magnification. The white zone adjacent to the copper is the martensite layer which tested above 600 standard Brinell hardness. The diamond impressions were made with a Tukon hardness tester and it will be noted that the impressions are large in the copper, small in the martensite zone, and larger in the original rail steel structure. Fig. 5b shows the junction of the copper and martensite layer at 600× magnification. The needle-like structure in the steel indicates the martensite structure.

Charpy Impact Tests

Two specimens of each type of weld were used to make one Charpy specimen from each. These were unnotched specimens and were tested with the weld side in tension. Companion specimens were cut from the other side of the rail heads for comparison and represent the rail steel which had not been welded. The results of Charpy tests are given in the following table:

Charpy Tests—Unnotched Specimens

Description of Specimen	*Torch Welded Specimens Ft.-Lb.*	*Thermit Welded Specimens Ft.-Lb.*
No. 1 bond area	7.1	5.7
No. 2 bond area	3.9	7.1
Avg.	5.5	6.4
No. 3 specimen without bond	139	171
No. 4 specimen without bond	133	168
Avg.	136	169.5

The bond areas gave low Charpy impact values for both types of welds, indicating that the welding produced brittleness in the steel.

Rolling-Load Tests of Rails with Bond Welds

Two rail specimens with each type of welded bond were used for rolling-load tests in one of the cradle type rolling-load machines which are ordinarily used to produce shelly rail failures. Standard carbon steel rails average about one million cycles for failure in these tests. The results of the rolling-load tests are shown in the following table:

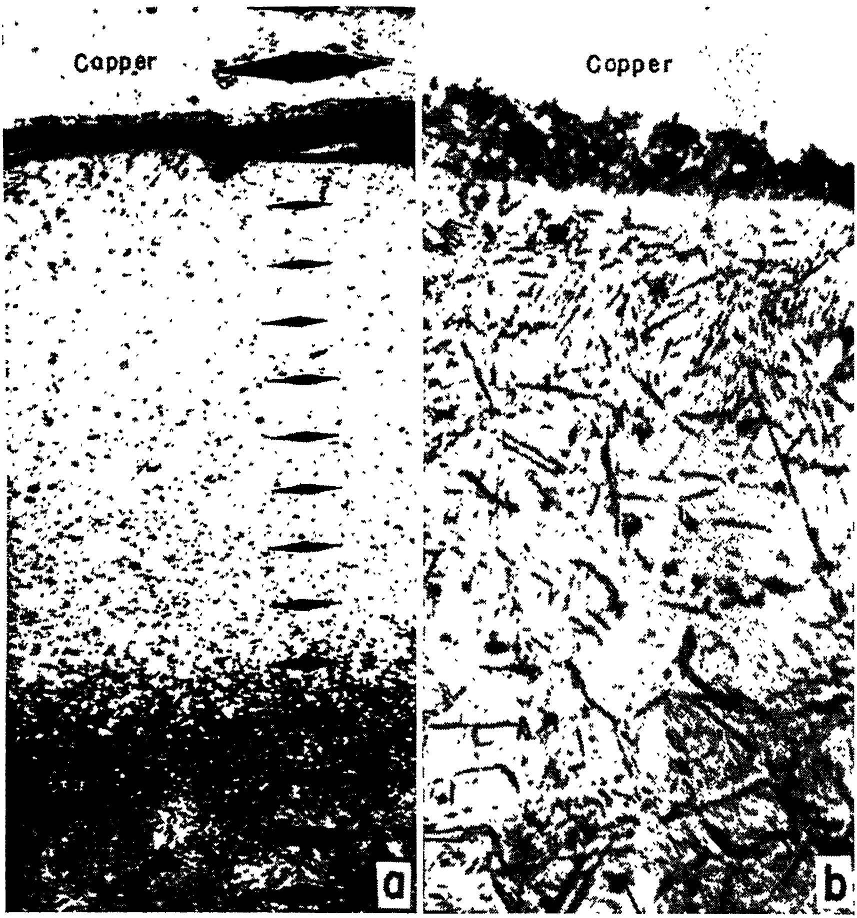


Fig. 5.—Metallographic Tests of Thermit Welded Bonds, Specimens Etched in 2-Percent Nital.

(a) Full width of heated zone. Mag. 100X. Diamond impressions are hardness tests. White zone adjacent to copper is martensite.

(b) Structure of martensite at 600X Mag.

a bond applied by the torch method and Fig. 3b shows a bond applied by the thermit welding process. In Figs. 3c and 3d it will be noted that the heat-affected zone on the torch welded rail is considerably larger and nearer the gage corner of the rail than on the thermit welded rail, as indicated by the black areas adjacent to the copper bond wire. The heat affected zone of the thermit weld is a layer of the steel only about 1/32 in. in thickness. This zone is too hard to saw with the best high speed hack saw blades. Both types of welds were submitted to metallographic examination, hardness tests, Charpy tests and rolling load tests.

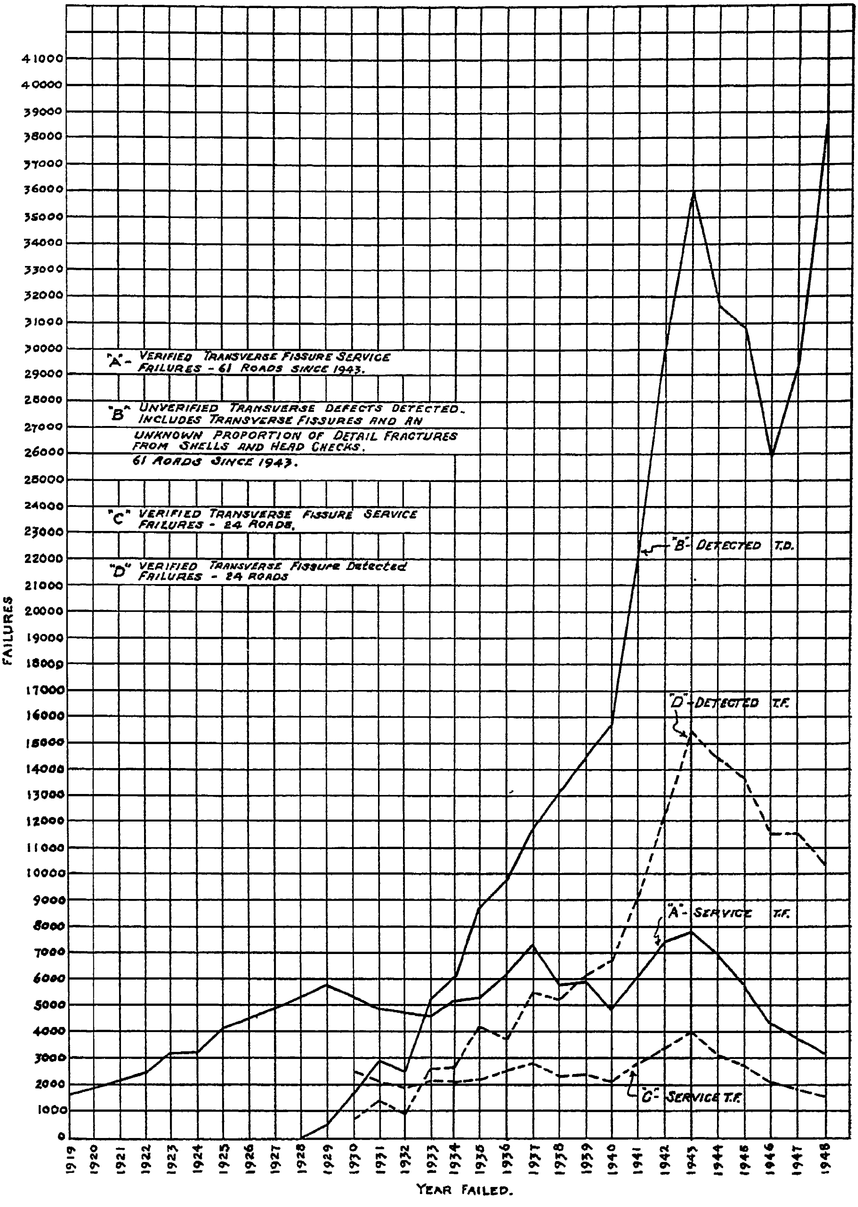


Fig. 1.—Annual Service Rail Failures Due to Transverse Fissures and Detected Failures Due to Unverified Transverse Defects Reported by All Roads.

Also, service and detected transverse fissure rails reported by roads which break their detected rails for verification. Rails of all ages made by all processes included. Engine burn fractures excluded.

RESULTS OF ROLLING-LOAD TESTS IN CRADLE ROLLING MACHINE
50,000-LB. WHEEL LOAD

	Cycles for Failure	
	Torch Welded Bonds	Thermit Welded Bonds
Specimen 1	1,128,000	1,579,200
Specimen 2	1,020,000	1,440,000

The rolling-load tests do not indicate that either type of welded rail bonds appreciably shortens the rail life in the severe conditions of the rolling load test. In fact, the thermit welds did not fail at the bond but failed about 2½ in. away from the bond.

Summary of Test on Welded Rail Bonds

The metallographic, hardness tests and Charpy tests indicate that some martensite was produced in the rails which is hard and brittle. However, this did not seem to produce early failure in the rolling-load tests. No conclusions should be drawn until many more laboratory and service tests have been made.

Report on Assignment 3

Rail Failure Statistics

Ray McBrian (chairman, subcommittee), C. J. Code, C. B. Bronson, G. F. Hand, J. G. Roney, A. A. Shillander.

These statistics present the rail failures reported to December 31, 1948, and are submitted as information.

In this report the term tranverse fissure includes those which originated in shatter cracks and other subsurface defects, such as hot torn steel, inclusions and welded engine burns. These statistics are the first that have been based on data reported by the roads on the latest revised forms, which require the segregation of vertical split head, horizontal split head and wheel burn failures. As the Chesapeake & Ohio could not so segregate its failures for previous years, the data supplied by that railway with the exception of mileages and 1948 failures, are not included in these statistics. Except where noted, the data presented herein covers open-hearth control cooled rail only.

Table 1 presents transverse fissure service and transverse defect detected rail failures reported by all 61 reporting roads, segregated by roads and by year failed. The transverse defects include transverse fissures and an unknown proportion of detail fractures from shells and head checks. These types cannot be segregated as the majority of the roads do not break their detected rails for verification.

Tables 2 and 2A present like data from 24 roads which did break their detected rails for verification and hence these tables are restricted to detected and service transverse fissure failures.

Fig. 1 is a graph of the data from Table 1 of this and previous reports and also, for comparison, that from Tables 2 and 2A. It will be noted that the curves A and C of service failures follow the same general pattern, as they should since service failures can be visually inspected, and hence are reasonably correct. Starting with the year 1946, however, the detected transverse defects reported by 61 roads, curve B, increase rapidly from 25,831 in 1946 to 38,445 in 1948. While the verified transverse fissure failures reported by the 24 roads in the same period dropped from 11,531 to 10,315. This down-

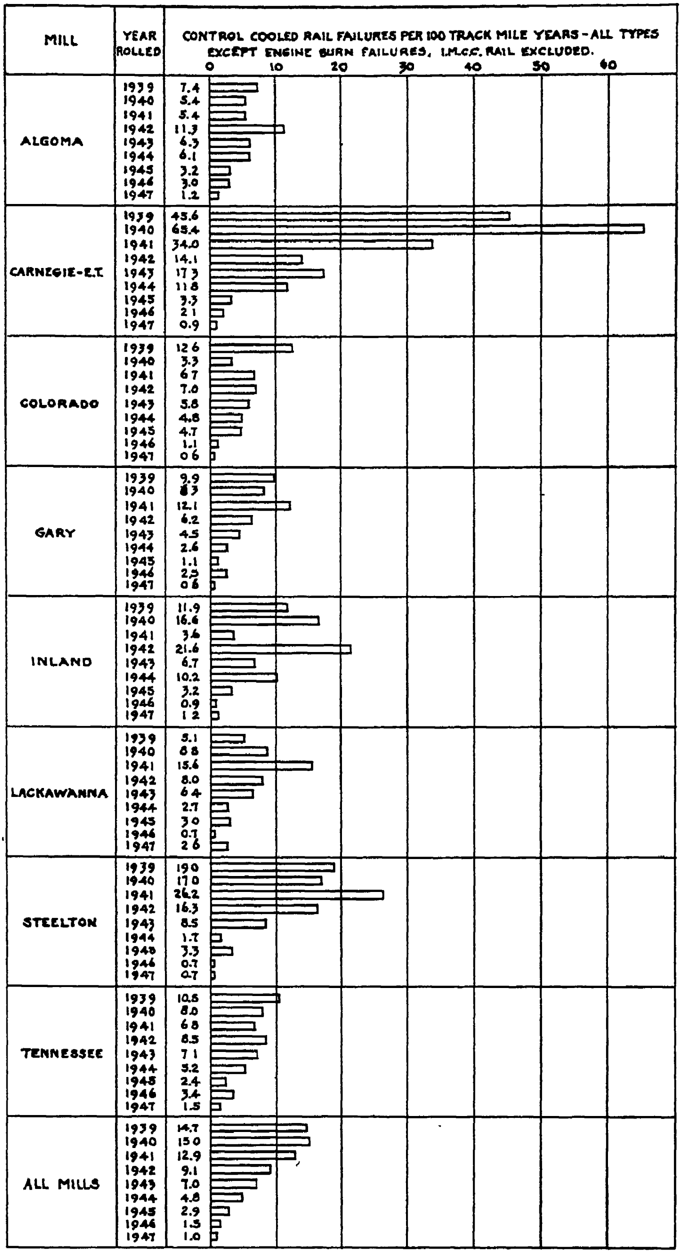


Fig. 3.—Control Cooled Rail Failure Rates to December 31, 1948 —All Types Except Engine Burn Fractures. Service and Detected, Not Weighted for Traffic,—by Mills.

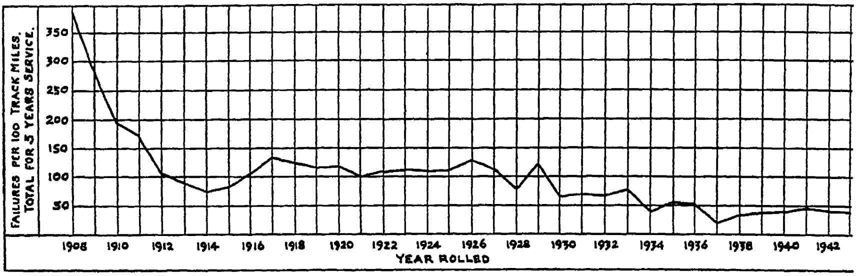


Fig. 2.—Service and Detected Rail Failures in the United States and Canada.

ward slope of curve D is closely paralleled by the service transverse fissure failures of both the 61 roads, curve A, and by curve C showing such failures on the 24 roads.

The rapid increase in the transverse defects on the 61 roads apparent since 1946 is probably due to one or more of the following causes:

(1) Increase in transverse defects from shells, etc.
(2) Increased ability of detector cars to detect them.
(3) Incorrect reporting by detector car operators of plain shells as transverse defects, such errors not being caught by roads which do not break their rails for verifications.

Table 3 lists the tons and track miles separately of control cooled and other process rails rolled in 1938–1947, incl.

Table 4 shows the combined service and detected failure rates of all types of failures accumulated in one to ten years' service of rail rolled in 1938–1947, incl. This table includes failures from all roads whose reports are complete. It differs from last year's Table 3 in that it is now restricted to control cooled failures only.

Fig. 2 is a continuation of the chart previously presented showing the rates of failure of all types accumulated in five years' service of all rollings from 1908–1943, incl., service and detected included.

Table 5 shows the track miles and 1948 failures by mill and by road of all types service and detected, in open-hearth control cooled rail rolled in 1938–1947, incl. It differs from Table 4 in last year's report in that the record of Brunorized rail has been discontinued and also in the segregation of engine burn fractures.

Table 6 presents the failures by mill and by type, exclusive of engine burn fractures, accumulated to December 31, 1948, in control cooled rail rolled in 1938–1947, incl. It differs from previous reports in that the record of intermediate manganese control cooled rail has been discontinued. The web failures and compound fissures and detail fractures predominate.

Table 7 segregates, by road, by mill and by type, the failures listed in Table 6. The 1948 engine burn fractures and those which were reported as accumulated in the years 1943 to 1948, incl., in rollings 1938–1947, incl., are shown separately and are not included with other type failures. The engine burn fractures could not be separated for the full ten years of observation as the classification of this type of failure was not adopted by the AAR until 1942, making it first available for the roads' reports of 1943 failures.

Table 7 shows the predominate type of failure on each road and how excessive failures by any type on one or more roads may affect a mill's record, although its record of that type of failure on other roads may be good.

(text continued on page 564)

TABLE 1.—Continued

Year Failed	Service Failures											Detected Failures										
	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total
NYO&W	33	20	20	32	16	62	6	1	24	24	238	0	0	0	0	0	53	0	56	2	0	111
N&W	21	10	7	9	2	3	1	5	3	2	63	44	53	63	49	34	40	40	58	17	129	527
NP	185	147	217	241	317	310	288	289	188	129	2311	310	227	326	470	589	440	471	702	475	431	4441
PRR**	442	323	425	440	517	365	415	290	259	255	3731	920	1158	1048	858	799	1026	909	646	644	1865	9873
P&LE	----	----	----	----	----	4	0	3	0	1	8	----	----	----	----	----	4	6	1	5	36	52
Reading	191	148	283	267	172	173	70	49	47	0	1400	0	0	0	0	0	367	735	287	321	1236	2946
RF&P	2	5	16	27	28	31	27	20	12	10	178	61	37	186	168	238	228	207	176	106	514	1921
Rutland	2	2	2	1	1	3	1	2	1	0	15	0	0	0	8	0	0	0	0	9	0	17
Seaboard	----	----	----	----	----	49	23	24	21	11	128	----	----	----	----	----	197	159	299	440	412	1507
SP (Pac. Lines)	590	347	356	452	426	445	267	209	179	162	3433	477	709	1424	1610	2002	1536	1377	1362	909	1243	12649
Sou. (Sys)	226	258	256	337	311	278	277	246	188	171	2548	1061	1101	2151	2454	3541	2360	1955	1835	1998	2643	21099
StLSF	----	----	----	----	----	111	142	102	101	74	530	----	----	----	----	----	573	655	415	532	664	2839
T&NO	----	----	----	----	----	239	186	123	66	112	726	----	----	----	----	----	795	924	837	739	951	4246
Tex & Pac	----	----	98	93	160	128	124	72	71	46	792	----	----	760	758	839	869	582	524	0	393	4725
UP (Sys)	1033	481	395	447	389	226	241	176	172	55	3615	2525	3022	4226	4479	3045	1587	1356	1148	4957	4149	30494
Virginian	39	30	27	16	12	11	13	10	4	6	168	0	126	90	173	114	114	0	0	0	152	769
W. Md.	50	53	43	48	35	26	27	14	33	25	354	72	82	148	228	152	184	133	144	224	418	1785
W&LE	----	----	----	----	----	3	3	5	1	0	12	----	----	----	----	----	0	3	3	0	8	14
All Roads	5915	4882	6069	7407	7795	6976	5707	4238	3801	3166	55956	14484	15732	21915	29848	36071	31978	30813	25831	29364	38445	274481

--No report received.
*Including IHB failures.
**Including LIRR & PRSL.

TABLE 1.—SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS, BY RAILROADS AND BY YEAR FAILED—ALL ROLLINGS BY ALL PROCESSES

Year Failed	Service Failures 1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total	Detected Failures 1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total
AT&SF	85	111	140	341	455	307	141	157	112	92	1941	326	377	275	566	831	647	538	580	388	1358	5886
ACL	67	114	121	250	218	267	50	51	43	14	1195	141	118	288	809	1220	870	1302	924	1120	1491	8283
Ban & Aroos	0	0	0	3	3	4	3	1	2	0	16	0	0	0	0	0	0	0	49	0	26	75
B&OCT	----	----	----	----	----	2	0	0	12	9	23	----	----	----	----	----	0	0	0	0	2	2
B&LE	----	----	----	----	----	10	6	9	3	5	33	----	----	----	----	----	0	0	0	0	0	0
B&M	25	11	20	20	42	64	17	11	26	31	267	706	927	785	661	884	276	695	315	212	379	5840
B&O	282	341	459	588	425	367	332	205	209	177	3385	431	609	797	1421	1269	780	844	978	801	713	8643
CP	164	225	501	425	381	238	274	214	184	181	2787	1780	2011	3813	5201	5964	5064	4957	3105	4338	3546	39779
C of Ga.	70	77	109	62	77	61	58	31	40	31	616	91	130	248	223	407	179	157	184	0	426	2045
C of NJ	69	87	81	77	77	71	48	45	61	65	681	0	0	0	0	0	0	0	3	0	0	3
C&EI	15	15	23	31	48	51	62	57	42	33	377	89	96	120	138	271	352	304	338	316	317	2341
C&O—Ches Dist.	145	93	100	123	107	71	57	68	88	64	916	786	533	539	417	540	393	458	465	559	1108	5798
C&O—PM Dist.	2	2	0	9	15	4	1	1	0	0	34	27	20	14	111	124	87	27	23	0	11	444
C& NW	47	62	78	162	168	160	135	137	168	149	1266	465	631	820	1463	1495	1578	1641	1176	1461	976	11706
CB&Q	151	161	199	272	323	287	244	141	152	144	2074	62	668	747	774	1733	1245	1342	1408	885	954	10418
CI&L	----	----	----	----	----	12	16	8	6	7	49	----	----	----	----	----	19	21	57	2	114	213
CMStP&P	45	73	77	119	136	136	132	79	87	89	973	285	311	340	684	468	1062	1083	1069	1173	914	7389
CRI&P	74	91	115	158	247	183	168	123	127	83	1369	336	269	136	390	605	645	643	527	552	596	4699
C&S	----	----	----	----	----	26	21	3	10	3	63	----	----	----	----	----	28	47	82	17	189	363
D&H	----	----	----	----	----	67	31	14	19	12	143	----	----	----	----	----	192	196	114	111	314	927
DL&W	72	56	85	96	23	27	29	36	22	17	463	400	140	0	1089	369	333	300	303	375	319	3628
D&RGW	----	----	----	----	----	203	212	159	22	31	627	----	----	----	----	----	114	254	190	14	695	1267
Erie	133	110	129	210	207	177	99	98	87	58	1308	350	238	599	405	1133	971	549	666	619	776	6306
Fla. EC	----	----	----	----	----	152	92	67	86	55	452	----	----	----	----	----	367	119	164	279	182	1111
GN	246	232	224	225	261	243	247	266	175	175	2294	142	171	150	258	366	430	535	516	430	1531	4529
GM&O—So. Rgn.	83	62	85	57	48	29	54	----	26	35	479	0	0	0	28	298	306	60	----	265	274	1231
GTW	----	----	----	----	----	43	43	13	20	27	146	----	----	----	----	----	112	112	83	89	110	506
IC (Sys.)	520	474	556	699	534	311	197	64	65	59	3479	596	727	471	1483	2000	1925	1907	1314	1418	1650	13491
KCS	----	----	----	----	----	14	21	4	0	10	49	----	----	----	----	----	178	66	94	0	94	432
L&HR	8	11	2	10	1	8	0	0	4	0	44	0	22	0	24	0	24	13	12	6	0	101
L&NE	5	4	1	8	3	5	2	7	2	5	42	0	26	0	27	12	4	15	16	13	36	149
LV	41	30	30	79	41	33	49	22	22	14	361	218	6	150	171	128	189	156	67	127	55	1267
L&N	178	130	139	202	217	160	159	116	133	115	1549	408	530	561	925	800	747	684	648	653	933	6889
Me. Cen.	----	----	----	----	----	12	15	14	0	0	41	----	----	----	----	----	21	63	50	0	0	134
MStP&SSM	----	----	----	----	----	13	49	23	30	21	136	----	----	----	----	----	39	24	96	90	95	344
MKT	80	66	110	81	131	92	57	28	31	30	706	61	132	4	455	249	515	214	141	118	576	2465
Mo Pac RR	----	----	----	----	228	----	----	----	----	----	228	----	----	----	----	1328	----	----	----	----	----	1328
Mo Pac Lines	----	----	----	----	68	25	24	31	42	4	194	----	----	----	----	502	728	399	462	507	553	3151
NC&StL	30	35	48	39	57	58	43	32	19	9	370	42	115	110	126	218	172	184	68	84	104	1223
NYC (Sys)*	433	357	462	617	652	406	344	225	202	173	3871	562	352	428	623	844	559	1119	750	724	1484	7445
NYC&StL	----	----	----	----	192	86	47	29	45	37	436	----	----	----	----	392	318	199	215	172	128	1424
NYC Transit	----	----	----	----	----	3	3	6	2	15	29	----	----	----	----	----	0	0	0	0	0	0
NYNH&H	31	28	30	34	24	21	14	3	5	4	194	110	58	98	121	268	136	74	86	68	172	1191

TABLE 2A.—SERVICE TRANSVERSE FISSURE FAILURES—ALL ROLLINGS BY ALL PROCESSES—SAME ROADS AS IN TABLE 2

	Service Failures																			
Year Failed	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total
AT&SF	142	114	84	64	46	35	46	92	43	85	111	140	341	455	307	141	157	112	92	2,607
Ban & Aroos	7	2	1	1	0	0	0	0	0	0	0	0	3	3	4	3	1	2	0	27
CP	138	109	90	103	113	121	134	138	114	164	225	501	425	381	238	274	214	184	181	3,847
C&EI	18	18	28	39	23	14	18	22	23	15	15	23	31	48	51	62	57	42	33	580
CB&Q	----	----	----	165	152	214	164	107	134	151	161	199	272	323	287	244	141	152	144	3,070
CMStP&P	26	45	105	125	99	71	74	53	46	45	73	77	119	136	136	132	79	87	89	1,017
C&S	----	----	----	----	----	----	----	----	----	----	----	----	----	----	26	21	3	10	3	63
Erie	156	175	181	179	187	171	167	229	123	133	110	129	210	207	177	99	98	87	58	2,876
GTW	----	----	----	----	----	----	----	----	----	----	----	----	----	----	43	43	13	20	27	146
GN	189	141	126	128	143	179	246	276	215	246	232	224	225	261	243	247	266	175	175	3,937
L&N	285	268	220	182	215	181	253	229	178	178	130	139	202	217	160	159	116	133	115	3,560
MKT	31	32	30	17	20	33	39	30	35	80	66	110	81	131	92	57	28	31	30	973
NC&StL	22	50	42	58	20	19	50	36	19	30	35	48	39	57	58	43	32	19	9	686
NYC System	340	306	299	306	272	318	381	361	389	433	357	462	617	652	406	344	225	202	173	6,843
NYC&StL	----	----	----	----	----	----	----	----	----	----	----	----	----	192	86	47	29	45	37	436
NYNH&H	40	25	24	40	59	34	37	48	39	31	28	30	34	24	21	14	3	5	4	540
N&W	43	41	29	50	33	23	38	36	22	21	10	7	9	2	3	1	5	3	2	378
NP	131	171	160	126	169	168	171	259	213	185	147	217	241	317	310	288	289	188	129	3,879
PRR	717	426	345	345	430	414	544	672	513	442	323	425	440	517	365	415	290	259	255	8,137
P&LE	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4	0	3	0	1	8
RF&P	----	1	3	5	4	4	2	4	3	2	5	16	27	28	31	27	20	12	10	204
Rutland	3	1	0	1	0	1	1	1	1	2	2	2	1	1	3	1	2	1	0	24
Va.	7	24	24	28	33	30	23	36	34	39	30	27	16	12	11	13	10	4	6	407
WMd.	255	148	94	94	62	87	116	70	133	50	53	43	48	35	26	27	14	33	25	1,413
Total	2550	2097	1885	2056	2080	2117	2504	2759	2277	2332	2113	2819	3381	3999	3088	2702	2095	1806	1598	46,258

TABLE 2.—VERIFIED DETECTED TRANSVERSE FISSURE FAILURES BY RAILROAD AND BY YEAR FAILED REPORTED BY ROADS WHICH BREAK THEIR DETECTED RAILS—ALL ROLLINGS BY ALL PROCESSES

	Detected Failures																			
Year Failed	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Total
AT&SF	----	0	0	13	77	121	59	247	194	326	377	275	566	831	647	538	580	388	298	5,537
Ban & Aroos	----	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	0	26	75
CP	----	351	214	372	834	899	999	1501	1239	1780	2011	3813	5201	5964	5064	4957	3105	4338	3545	46,187
C&EI	----	59	0	74	43	65	29	65	77	89	96	120	138	271	352	304	338	316	312	2,748
CB&Q	----	----	----	174	322	315	447	413	602	662	668	747	774	1733	1245	1342	1408	885	887	12,624
CMStP&P	----	49	0	156	179	247	197	357	288	285	311	340	684	468	1062	1083	1069	1173	734	8,682
C&S	----	----	----	----	----	----	----	----	----	----	----	----	----	----	28	47	82	17	56	230
Erie	7	4	0	75	0	165	0	166	264	350	238	599	405	1133	971	549	666	619	595	6,806
GTW	----	----	----	----	----	----	----	----	----	----	----	----	----	----	112	112	83	89	106	502
GN	25	0	0	6	144	114	88	69	92	142	171	150	258	366	430	535	516	430	631	4,167
L&N	165	0	0	358	19	341	488	577	530	408	530	561	925	800	747	684	648	653	662	9,096
MKT	12	29	76	31	98	74	77	167	169	61	132	4	455	249	515	214	141	118	280	2,902
NC&StL	2	0	0	0	40	45	17	42	70	42	115	110	126	218	172	184	68	84	87	1,422
NYC System	107	83	182	253	114	191	322	428	430	562	352	428	623	844	559	1119	750	724	690	8,761
NYC&StL	----	----	----	----	----	----	----	----	----	----	----	----	----	392	318	199	215	172	128	1,424
NYNH&H	67	159	106	101	100	82	60	101	92	110	58	98	121	268	136	74	86	68	132	2,019
N&W	20	0	5	0	74	0	0	84	45	44	53	63	49	34	40	40	58	17	29	655
NP	----	0	0	81	19	324	173	292	246	310	227	326	470	589	440	471	702	475	355	5,500
PRR	260	576	403	851	440	1073	690	757	857	920	1158	1048	858	799	1026	909	646	644	404	14,319
P&LE	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4	6	1	5	0	16
RF&P	----	0	0	36	0	67	44	53	52	61	37	186	168	238	228	207	176	106	147	1,806
Rutland	0	0	7	0	0	3	0	0	0	0	0	0	8	0	0	0	0	9	0	27
Va.	----	0	0	0	0	0	0	0	0	0	126	90	173	114	114	0	0	0	1	618
WMd.	----	0	0	0	106	0	0	86	0	72	82	148	228	152	184	133	144	224	210	1,769
Total	665	1310	993	2581	2609	4126	3690	5405	.5247	6224	6742	9106	12230	15463	14394	13707	11531	11554	10315	137,892

TABLE 5.—TRACK MILES AND 1948 FAILURES, ALL TYPES, IN ROLLINGS 1938 TO 1947, INCL., OPEN-HEARTH CONTROL COOLED RAIL ONLY

Road	Track Miles by Mill											1948 Failures Only	
	Alg.	*Carn.*	*Colo.*	*Dom.*	*Gary*	*Inld.*	*Lacka.*	*Md.*	*Stltn.*	*Tenn.*	*Total*	*EBFs Excl.*	*EBFs Only*
AT&SF			2, 982		782	69			46		3, 879	69	0
ACL		93							382	586	1, 061	23	2
B&O		848			455	23	186		375		1, 882	335	108
B & Aroos		8							98		101	2	0
B&O-CT					19	14					33	0	0
B&LE		113									113	4	0
Bos&Alb					8		189		5		202	6	0
B&M		152					174		135		461	8	1
CP	3, 638			124			132				3, 894	331	0
C of Ga										328	328	24	0
C of NJ									227		227	26	0
C&O-E Regn					1, 039	507			197		1, 743	232	223
C&O-PM Dist	95	176				90	52				413	3	0
C&EI					245	50					295	11	1
C&NW					729	194	46				969	81	0
CB&Q			909		789	171					1, 869	24	0
CCC&StL					811	8	46				865	31	2
CI&L					93						93	0	0
CMStP&P					1, 124	320					1, 444	23	1
CRI&P			454		1, 220	378					2, 052	79	0
C&S			39								39	0	0
D&H									473		473	176	3
DL&W		70					284				354	5	0
D&RGW			546								546	103	0
Erie		696			275	38	141				1, 150	38	30
FEC		11							45	361	417	8	2
GM&O-S Regn										334	334	35	0
GTW					292	74	16				382	12	0
GN					631	167	272				1, 070	73	0
IC					1, 264	503				407	2, 174	75	3
IHB						22					22	28	0
KCS					381	64			10		455	3	0
L&HR									26		26	0	0
L&NE		3							28		31	0	0
LV							264				264	21	0
L&N					197					1, 635	1, 832	161	3
Me Cen							52				52	0	0
Mich Cen	348				252						600	16	11
MStP&SSM					87	33	48				168	0	0
MKT			76		429	83					588	7	0
MPRR			1, 093		489	236				132	1, 950	124	1
MP Lines		15	315							144	474	10	0

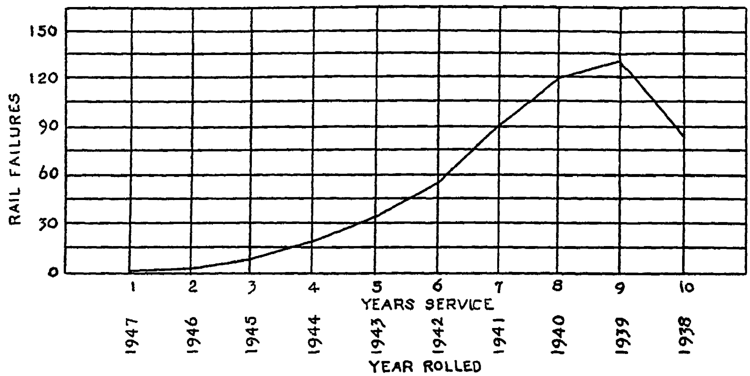


Fig. 4.—Control Cooled Rail Failures to December 31, 1948 Per 100 Track Miles —All Types Excluding Engine Burn Fractures—Service and Detected.

TABLE 3.—TONS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1938–1947, INCL., INCLUDED IN THESE STATISTICS

Year Rolled	*OH Control Cooled Only*		*Brunorized and Other Process*		*Total*	
	Tons	*Track Miles*	*Tons*	*Track Miles*	*Tons*	*Track Miles*
1938	359, 170	2, 020.15	60, 973	362.14	420, 143	2, 382.29
1939	787, 827	4, 212.57	54, 128	309.72	841, 955	4, 522.29
1940	871, 310	4, 730.95	52, 846	316.44	924, 156	5, 047.39
1941	1, 051, 545	5, 644.65	40, 414	232.09	1, 091, 959	5, 876.74
1942	1, 098, 604	5, 936.86	14, 129	95.61	1, 112, 733	6, 032.47
1943	1, 274, 168	6, 908.42	11, 443	77.24	1, 285, 611	6, 985.66
1944	1, 554, 522	8, 396.26	7, 845	54.12	1, 562, 367	8, 450.38
1945	1, 504, 778	8, 052.80	0	0	1, 504, 778	8, 052.80
1946	1, 234, 661	6, 575.15	0	0	1, 234, 661	6, 575.15
1947	1, 318, 437	6, 919.94	0	0	1, 318, 437	6, 919.94
Total	11, 055, 022	59, 397.75	241, 778	1, 447.36	11, 296, 800	60, 845.11

TABLE 4.—SERVICE AND DETECTED FAILURES OF ALL TYPES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1948, PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS, FROM ALL MILLS

Year Rolled	*Years of Service*									
	1	*2*	*3*	*4*	*5*	6	*7*	*8*	*9*	*10*
1937	------	------	------	------	------	29.7	44.1	66.7	98.4	93.5
1938	------	------	------	------	28.5	39.6	51.9	65.2	83.4	85.1
1939	------	------	------	15.0	21.4	40.4	70.4	102.6	131.5	
1940	------	------	12.5	17.5	34.3	67.9	92.9	119.8		
1941	------	4.2	9.3	24.3	46.3	66.1	90.6			
1942	2.3	6.0	11.6	24.9	37.7	54.8				
1943	3.4	8.4	16.5	23.9	34.9					
1944	3.6	7.2	13.8	19.4						
1945	1.4	4.1	8.6							
1946	1.2	2.9								
1947	0.9									

Note: 0 indicates figures are not available.

TABLE 6.—ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1938 TO 1947, INCL., FROM DATE ROLLED TO DECEMBER 31, 1948, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE

OH Control Cooled Rail Only

Mill	Accumulated Failures to December 31, 1948 (Excl. EBFs)										Avg. Track Miles	Track Mile Years	Failures Per 100 Track Mile Years
	TF Ver. U of I	CF and DF	VSH	HSH	Other Head	Broken	Web		Base	All Types			
							In Jt.	Other					
Algona	2	2	298	15	175	49	239	54	342	1, 176	4, 080.96	17, 801	6.61
Carnegie (ET)	0	280	93	86	81	223	4435	1392	11	6, 601	5, 378.31	24, 295	27.17
Colorado	0	1234	529	428	357	112	103	558	22	3, 343	12, 455.36	53, 908	6.20
Dominion	0	0	2	0	16	0	0	5	3	26	123.58	884	2.94
Gary	1	1141	208	92	210	313	1671	560	85	4, 281	14, 641.60	69, 074	6.20
Inland	7	234	60	26	43	152	622	295	35	1, 474	3, 171.83	16, 586	8.89
Lackawanna	6	207	31	37	55	126	615	65	141	1, 283	3, 796.37	17, 525	7.32
Maryland													
Steelton	36	1357	58	208	185	572	597	549	7	3, 569	6, 418.02	27, 519	12.97
Tennessee	0	154	258	520	279	449	627	440	155	2, 882	7, 588.92	38, 968	7.40
All Mills	52	4609	1537	1412	1401	1996	8909	3918	801	24, 635	57, 654.95	266, 560	9.24
Failure per 100 Track Mile Years	0.02	1.73	0.58	0.53	0.52	0.75	3.34	1.47	0.30	9.24			

TABLE 5.—Continued

Road	Track Miles by Mill											1948 Failures Only	
	Alg.	Carn.	Colo.	Dom.	Gary	Inld	Lacka	Md.	Stln.	Tenn	Total	EBFs Excl.	EBFs Only
NC&StL					5					433	438	104	1
NYC-E					58		1, 106				1, 164	185	0
NYC-W					575	90	156				821	48	24
NCY&StL					429	95	140				664	42	0
NYNH&H		350							317		667	47	16
N&W		967							322		1, 289	138	35
NP			355		961	50	444				1, 810	51	14
PRR		1, 284			782	141	40		1, 389		3, 636	2, 293	183
P&E						16					16	0	0
P&LE		167									167	4	0
Reading									336		336	7	1
RF&P									117		117	183	8
Rutland							3				3	3	0
SAL									714	569	1, 283	32	1
StLSF					10	40				729	779	27	0
SP			2, 628						354	356	3, 338	299	14
SoRy					115				651	1, 337	2, 103	111	23
T&NO			602						55	16	673	12	0
T&P			474							222	696	8	0
UP			1, 982		1, 135	203					3, 320	1, 199	2
Va		126					5		227		358	64	0
WMd		64							86		150	9	0
W&LE		245									245	27	0
Total	4, 081	5, 378	12, 455	124	15, 681	3, 679	3, 796	0	6, 615	7, 589	59, 398	7, 100	718

TABLE 7.—Continued

Roads	TF Ver U of I	CF and DF	VSH	HSH	Other Head	Broken	Web: In Jt.	Web: Other	Base	FAILURE TOTALS: EBFs Excl.: Accum. Total	FAILURE TOTALS: EBFs Excl.: 1948 Only	FAILURE TOTALS: EBFs Only: 1943–1948	FAILURE TOTALS: EBFs Only: 1948 Only
MKT			5	2	5		9	2		23	4	6	
MP, RR		3	3	4	4	3	12	80	1	110	32	1	1
NC&StL			1				1	1		3	1		
NYC—E		18	1	4			28			51	21	1	
NYC—W	1	22	5	3	1		30			62	20	23	21
NYC&StL		2	2		14	9	30	32	1	90	31		
NP		10	8		21	33	13	12	8	105	23	14	8
PRR		33	8	4	1	21	1297	248	1	1613	421	27	19
StLSF					1			1		2	2		
So Ry						2	1	3		6			
UP		860	20	52	46	5	13	87	2	1085	443	5	1
Total	1	1141	208	92	210	313	1671	560	85	4281	1314	152	89
INLAND													
AT&SF	1									1	1		
B&O		1					3			4	1		
B&O—CT		1								1			
C&O—PM		1	2		3				1	7	2		
C&EI			2				1	4		7	1	3	
C&NW		3	4		3	23	13	1	5	52	27		
CB&Q		1	2	1	1	4		1	2	12	5		
CMStP&P		1	3	1	4	36		9	4	58	15	1	1
CRI&P		1	4		2	30	6	2	7	52	18		
CCC&StL					1		1	1		3	1		
Erie			1			1	1	2		5	2		
GTW			1		1	26			6	34	3		
GN		2	9		10		4		2	27	6		
IC		9	9	2		3	23	5		51	9	2	2
IHB						5	35	3		43	28		
KCS			7				1	1		9	1		
MStP&SSM						5		1	4	10			
MKT		1	4	1	2			3		11	2		
MP RR		5	3	6	7	5	17	91		134	17		
NYC—W		3	2				152	4		161	25		
NYC&StL		3			2		8	2	2	17	2		
NP			1			1			2	4	2		
PRR		14	1	2	1	12	351	133		514	73	2	2
UP	6	188	5	13	6	1	6	32		257	142	1	1
Total	7	234	60	26	43	152	622	295	35	1474	383	9	6
LACKAWANNA													
B&O		14	1		3	2	14	10		44	35	24	6
Bos&Alb		1	1				3	2	2	9	5		
Bos&Me			1		2	12		1	2	18	2		
CP			2		18		3	5	28	56	16		
C&O—PM					1	2			2	5	1		
CCC&StL			1		5		1	4		11	7		
DL&W		2	2	4	2		11	3	10	34	4	1	
Erie		9				2		9	1	21	5	2	
GN		26	5	1	7	1	8	2	5	55	15		
LV	2	2	1			12	7	20	23	67	21		
Me. Cen.					1				1	2			
MStP&SSM						2			1	3			
NYC—E	2	97	10	28		15	207	3	6	368	164	9	
NYC—W		2		1			240			243	3	9	3
NYC&StL	2				10	3	61	4		80	9		
NP		3	7	1	6	30	3	2	46	98	20	4	2
PRR		51		2		34	57			144	62	1	
Rutland						11			14	25	3		
Total	6	207	31	37	55	126	615	65	141	1283	372	50	11
STEELTON													
AT&SF						4	2			6	2		
ACL							2			2	2		
B&O	4	16	5	7	3	4	26	35		100	42	70	34
Ban&Aroos			1			1				2	2		
Bos&Me	2	1	1	1	6	8		5	1	25	2	1	1
C of NJ	1	3				11	36	1		52	26		

TABLE 7.—ACCUMULATED FAILURES OF ALL TYPES IN OH CONTROL COOLED RAIL ONLY, IN ROLLINGS 1938–1947, INCL., ACCUMULATED TO DECEMBER 31, 1948, SEGREGATED BY ROADS AND MILLS, FROM TABLE 6, EXCLUSIVE OF ENGINE BURN FRACTURES SHOWN SEPARATELY FOR 1948 ONLY AND TOTAL ACCUMULATED 1943–1948, INCL.

Roads	TF Ver U of I	CF and DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURE TOTALS			
										EBFs Excl		EBFs Only	
							In Jt.	Other		Accum. Total	1948 Only	1943–1948	1948 Only
ALGOMA													
CP	1	2	297	14	174	48	235	52	339	1162	312	----	----
C&O—PM	1	----	1	----	----	----	----	----	----	2	----	----	----
Mich Cen	----	----	----	1	1	1	4	2	3	12	6	1	----
Total	2	2	298	15	175	49	239	54	342	1176	318	1	0
CARNEGIE (ET)													
B&O	----	45	33	13	40	11	204	102	----	448	217	85	44
B&LE	----	7	----	----	----	8	1	----	3	19	4	----	----
B&M	----	----	----	1	3	3	----	23	----	30	4	----	----
C&O—PM	----	----	2	----	1	----	----	----	----	3	----	----	----
DL&W	----	----	1	1	----	----	----	----	----	2	1	----	----
Erie	----	13	8	4	4	6	8	20	4	67	19	38	30
FEC	----	----	----	----	2	----	5	----	----	7	1	----	----
L&NE	----	----	1	----	----	----	----	----	----	1	----	----	----
NYNH&H	----	8	12	5	----	5	26	1	1	58	30	7	7
N&W	----	91	1	27	----	----	48	63	----	230	96	62	21
PRR	----	80	28	24	19	76	4133	1153	1	5514	1034	150	147
P&LE	----	10	1	4	1	----	----	2	----	18	4	----	----
Va	----	26	1	3	----	86	----	7	----	123	17	----	----
WMd	----	----	----	----	----	4	----	2	----	6	6	----	----
W&LE	----	----	5	4	11	24	10	19	2	75	27	----	----
Total	0	280	93	86	81	223	4435	1392	11	6601	1460	342	249
COLORADO													
AT&SF	----	95	83	37	9	48	11	30	3	316	61	----	----
CB&Q	----	1	35	16	1	5	1	3	3	65	9	----	----
CRI&P	----	3	20	1	5	14	2	----	4	49	16	----	----
D&RGW	----	137	22	13	8	5	29	21	----	235	103	----	----
MKT	----	----	3	4	1	1	----	2	----	11	1	----	----
MP Lines	----	----	3	2	1	4	1	----	----	11	5	----	----
MP RR	----	6	50	9	47	9	31	22	3	177	54	----	----
NP	----	2	5	----	4	4	3	6	----	24	6	14	4
SP	----	14	246	217	191	15	9	340	3	1035	159	18	1
T&NO	----	3	11	12	15	5	----	9	----	55	12	----	----
T&P	----	----	4	----	1	2	3	2	----	12	2	----	----
UP	----	973	47	117	74	----	13	123	6	1353	613	4	----
Total	0	1234	529	428	357	112	103	558	22	3343	1041	36	5
DOMINION													
CP	----	----	2	----	16	----	----	5	3	26	3	----	----
Total	0	0	2	0	16	0	0	5	3	26	3	0	0
GARY													
AT&SF	----	----	13	----	----	3	4	----	----	20	5	----	----
B&O	----	1	4	2	7	1	56	8	5	84	40	42	24
B&O—CT	----	----	----	----	----	----	1	----	----	1	----	----	----
Bos& Alb	----	----	----	----	----	----	1	----	----	1	1	----	----
C& EI	----	----	4	----	4	----	15	6	----	29	10	4	1
C&NW	----	9	8	1	18	28	37	6	4	111	54	----	----
CB&Q	----	5	7	3	4	4	5	8	1	32	10	----	----
CMStP&P	----	----	4	----	----	38	----	7	7	56	8	----	----
CRI&P	----	5	23	2	16	92	14	10	19	181	45	----	----
CCC&StL	----	2	3	2	23	1	18	14	----	63	23	2	2
Erie	----	3	2	----	----	3	5	12	1	26	12	----	----
GTW	----	1	3	----	5	54	3	4	29	99	9	----	----
GN	----	115	17	1	21	1	13	----	----	168	52	----	----
IC	----	11	28	8	8	8	60	10	4	137	36	1	1
KCS	----	34	14	4	----	4	2	9	1	68	1	12	----
L&N	----	1	----	----	----	----	----	1	----	2	----	----	----
Mich Cen	----	6	21	----	11	----	3	3	1	45	10	14	11
MStP&SSM	----	----	4	----	----	8	----	1	----	8	----	----	----

TABLE 8.—ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, BY ROAD, MILL AND YEAR ROLLED TO OCTOBER 1, 1949

Roads	*Mills*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*Total*
CP	Algoma						1						1
PM	Algoma						1						1
NYNH&H	Carnegie(ET)			1(d)									1
N&W	Carnegie(ET)					1							1
C&O	Gary		2(b)			1(b)	1(b)						4
C&NW	Gary		1(a)	1(a)									2
CB&Q	Gary		3(a)										3
GN	Gary		1(a)										1
NYC	Gary				1(a)								1
Wabash	Gary			1(a)									1
AT&SF	Inland							1					1
C&O	Inland	1	4(c)	3	2			6			1	1	18
GN	Inland					1(e)							1
UP	Inland					3	3						6
LV	Lackawanna								1	1			2
NYC	Lackawanna								1	1	1		3
NYC&StL	Lackawanna								2				2
AT&SF	Steelton			2									2
B&O	Steelton							1	2	1			4
B&M	Steelton						2						2
C of NJ	Steelton									1			1
C&O	Steelton	4		1	4		1						10
D&H	Steelton				1	2	1(f)			1			5
MP	Steelton			1									1
N&W	Steelton					1	1		4				6
NYNH&H	Steelton			3		2	1		1	1			8
PRR	Steelton		2										2
RF&P	Steelton			1			1						2
SAL	Steelton							2		1			3
SoRy	Steelton							1		1			2
SP	Steelton		16	2	5	3							26
Va.	Steelton						1						1
TOTAL		5	29	16	13	14	14	11	11	8	2	1	124
	Algoma						2						2
	Carnegie(ET)			1		1							2
	Colorado	*											0
	Dominion												0
	Gary		7	2	1	1	1						12
	Inland	1	4	3	2	4	3	7			1	1	26
	Lackawanna								4	2	1		7
	Maryland	*	*	*	*	*	*	*	*	*	*	*	0
	Steelton	4	18	10	10	8	8	4	7	6			75
	Tennessee												0
All Roads	All Mills	5	29	16	13	14	14	11	11	8	2	1	124

*No CC rail rolled.

Note: (a) TF from shatter cracks due to use of improper cooling box covers. (b) TF from welded engine burns. (c) One TF from welded engine burn. (d) TF from silicate inclusion. (e) TF from small hole near welded joint. (f) TF from inclusion. Summary—8 TFs from shatter cracks, 5 TFs from welded engine burns, 2 TFs from inclusions, 1 TF from small hole near welded joint, 108 TFs from hot torn steel

TABLE 7.—Continued

Roads	TF Ver U of I	CF and DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURE TOTALS			
										EBFs Excl.		EBFs Only	
							In Jt.	Other		Accum. Total	1948 Only	1943–1948	1948 Only
D&H	5	296	9	87	35	10	18	155	2	617	176	21	3
FEC	----	----	----	1	----	----	----	----	----	1	1	----	----
KCS	----	----	----	----	1	----	----	5	----	6	1	4	----
NYNH&H	5	21	2	1	----	2	15	----	----	46	17	9	9
N&W	6	86	----	4	1	----	11	16	----	124	42	31	14
PRR	----	443	4	10	65	424	465	11	----	1422	703	16	15
Reading	----	----	----	----	----	6	----	1	----	7	7	1	1
RF&P	1	272	5	4	1	----	7	----	----	290	183	8	8
SAL	3	6	2	3	----	55	3	----	1	73	13	1	----
SP	6	13	25	85	70	6	4	311	2	522	64	9	5
So Ry	2	157	2	3	2	9	1	----	----	176	41	25	6
T&NO	----	----	----	1	----	----	----	1	----	2	----	----	----
Va	1	43	1	1	1	30	7	8	1	93	47	----	----
WMd	----	----	1	----	----	2	----	----	----	3	3	----	----
Total	36	1357	58	208	185	572	597	549	7	3569	1374	196	96
TENNESSEE													
ACL	----	2	12	3	----	3	22	5	2	49	21	5	2
C of Ga	----	2	2	4	6	8	44	1	6	73	24	----	----
FEC	----	1	----	1	1	4	7	----	2	16	6	2	2
CM&O—SoRgn	----	14	8	2	5	2	9	8	26	74	35	----	----
IC	----	1	8	4	2	5	64	5	3	92	30	----	----
L&N	----	75	80	194	55	80	258	66	28	836	161	35	3
MP Lines	----	1	1	2	3	1	3	1	11	23	6	----	----
MPRR	----	----	3	7	6	6	18	9	2	51	21	----	----
NC&StL	----	9	39	108	41	30	151	57	19	454	103	1	1
StLSF	----	21	23	12	23	39	7	36	----	161	25	2	----
SAL	----	3	8	9	----	57	5	2	14	98	19	4	1
SP	----	7	62	151	79	33	12	217	5	566	76	17	8
SoRy	----	17	9	22	57	178	14	30	7	334	70	20	17
T&P	----	1	3	1	1	3	13	3	30	55	6	1	----
Total	0	154	258	520	279	449	627	440	155	2882	603	87	34
All Mills	52	4609	1537	1412	1401	1996	8909	3918	801	24635	6868	873	490

(text continued from page 552)

Table 8 lists the transverse fissure failures in open-hearth control cooled rail verified at the University of Illinois, accumulated in rollings 1935–1945, incl. No transverse fissures have been reported in control cooled rail rolled since 1945. The reduction in the number of fissures due to hot torn steel from 21 in the 1936 rollings to none in the rollings of 1946 to 1948, incl., shows that the mills have overcome this manufacturing difficulty.

Fig. 3 charts the service and detected failure rates per 100 track mile-years for open-hearth control cooled rail separately for rollings 1939–1947, segregated by mills. All types of failures except engine burn fractures are included. Comparing this chart with Fig. 4 of last year's report we find that the expected effect of the exclusion of engine burn fractures is not apparent. Many web failures within joint bar limits, reported by one road, (see Tables 6 and 7) increased the failure rates of certain rollings from several mills.

Fig. 4 presents the open-hearth control cooled rail failures accumulated to December 31, 1948, from each of the rollings 1938–1947, per 100 track miles, all types of service and detected failures, except engine burn fractures, being included. This corresponds with Fig. 3 of last year's report except for the exclusion of the failure rates for other process rails. It is plotted from data in Table 4.

As stated in the report last year, it is hoped that other studies similar to the two submitted here will be made available to the committee from which studies the relative rail life, track labor requirements, tie life, and ballast renewal may be established for different traffic conditions and these data may be used by railroads generally as a guide in selecting a suitable rail section.

Study A

RESULT OF STUDY OF ILLINOIS CENTRAL RAILROAD
Test Sections of 112-lb. and 131-lb. Rail

131-lb. Rail

M.P. 132.00 to M.P. 152.24 (Laid in 1944)
(Station 11224 + 95 to Station 11293 + 98)

Total track miles maintained (106,747 track ft.)	20.21
No. turnouts maintained	21
No. railroad crossings maintained	3
No. public grade crossings maintained	22
No. private grade crossings maintained	6

112-lb. Rail

M.P. 163.68 to M.P. 172.73 (Laid in 1942)
M.P. 152.24 to M.P. 163.68 (Laid in 1943)
(Station 10142 + 58 to Station 11224 + 95)

Total track miles maintained (108,173 track ft.)	20.48
No. turnouts maintained	18
No. railroad crossings maintained	1
No. public grade crossings maintained	22
No. private grade crossings maintained	2

Both Test Sections Computed at 1944 Prices

Average annual traffic density—28,000,000 gross tons

Investment Charges Per Mile

Rail and Other Track Material				
Gross cost	$12,643		$14,413	
Less est. salvage	Cr 4,284		Cr 5,011	
Net cost	8,359		9,402	
Total cost to lay	1,338		1,473	
Total cost to place	9,697		10,875	
Estimated life—years	15		25	
Annual Cost				
Rail and other track material		$ 557		$ 376
Laying		89		59
Interest at 6%*		839		953
Total annual cost		$1,485		$1,388
Percent decrease in investment Cost				Cr 6.5

Maintenance Charges Per Mile

Annual Cost				
Labor (5-years avg. hours) 22914/20.48 at $.65		$ 727		
17920/20.66† at $.65				$ 564
Ties per mile	3,250		3,250	
Ties cost at $1.87 each	$ 6,078		$ 6,078	
Estimated life—years	16		21	
Tie cost per year		380		289
Total maintenance		$1,107		$ 853
Per saving—maintenance				Cr 22.9
Total annual cost		$2,592		$2,241
Saving by use of 131-lb. material				351
Percent saving				13.5

* On gross outlay for material and labor.
† Adjusted for 3 additional turnouts; 2 additional railroad crossings, and 4 additional highway crossings by data in AREA Manual, p. 22–15.

Report on Assignment 5

Economic Value of Various Sizes of Rail

C. M. Chumley (chairman, subcommittee), J. E. Armstrong, C. H. Blackman, W. J. Burton, B. Chappell, C. J. Code, J. L. Gressitt, G. F. Hand, C. B. Harveson, R. F. Logan, E. E. Mayo, Ray McBrian, B. R. Myers, R. E. Patterson, J. G. Roney, E. F. Salisbury, W. D. Simpson, G. L. Smith, H. F. Whitmore, Barton Wheelwright.

Your committee submits the following report of progress as information.

In past years several studies of the economical size of rail for various traffic densities have been presented, but it has always been difficult to secure factual data from experience comparing the maintenance cost and traffic life of the various rail sections under actual service conditions. Therefore, it is believed that the accompanying comparisons based on actual results obtained on two different railroads will be of especial interest and value.

Illinois Central Railroad Study

The committee report last year described two test sections, each 20 miles in length, of 112-lb. and 131-lb. rail which had been selected on the Illinois Central Railroad to provide a comparison of service performance and annual maintenance cost. These test sections adjoin each other and have nearly identical conditions affecting maintenance cost, including tonnage, roadbed, and operation. Study A is based on the actual man hours and units of material required for installation and maintenance for a period of five years. However, in order to provide a true comparison all unit costs for labor and material have been computed at 1944 prices for both sections. The salvage value for each section is based upon releasing rail of the same weight as placed which is a proper consideration for the purposes of this study. It will be noted from Study A that when allowance is made for the longer estimated life of the heavier rail, the annual investment cost for the 131-lb. section is $97 per mile per year, or 6.5 percent, less than that for the 112-lb. It was necessary to estimate the increased life of rail from results obtained on other roads, as the 131-lb. section had not been in service long enough on the Illinois Central to determine its tonnage life.

The savings in maintenance labor cost based on actual requirements over the five-year period average $163 per mile per year for the 131-lb. rail, and the estimated savings in tie replacement cost average $91. Thus a net saving of $351 per mile per year is indicated for the 131-lb. rail for the conditions of this study.

Pennsylvania Railroad Study

Through the courtesy of S. R. Hursh, assistant chief engineer—maintenance, Pennsylvania Railroad, the comparison shown in Study B gives the results obtained on that railroad with 155 PS, 133 RE, and 100 PS rail sections. These results are based on an annual traffic density of 38,000,000 gross tons and 1948 unit costs for labor and material.

The comparatively short life of the 100 PS section for this heavy traffic density results in annual replacement and maintenance costs that are much in excess of those for the two heavy rail sections.

Taking into consideration the longer life of the 155 PS section, the annual carrying charges for rail replacement are only $21 per year per mile more than for the 133 RE section. However, the annual savings in track labor are $1278 per mile per year for the 155 PS compared to the 133 RE; in tie renewals, $54; and in ballast replacement, $52. Thus, a net saving for the 155 PS versus the 133 RE of $1363 per mile per year is indicated for the conditions of this comparison.

INSTALLATIONS OF CONTINUOUS WELDED RAIL - SUMMARY TO DATE

Process	Maximum Continuous Lengths Welded Without Intervening Joints: Road	Feet	Total Length of Installation Track Feet	Number of welded Joints	Weight of Rail Lbs. per Yd.	Bars Applied	Maximum Wheel Load Lbs.	Annual Tonnage	Traffic: Pass.	Traffic: Frt.	Speed M.P.H.	Date Installed	In Tunnel or Open	Failures
"C1" Thermit (Type K) - -	(N. P.)	9867	9867	506	131 RE	No	37,000	Not known	Pass.	Frt.	30	Late 1942	Tunnel	1
	(G. N.)	5668	5668	290	110 RE	No	35,000	6,042,000	"	"	55	1937	Open	7
	(D. & H.)	7018	29515	1559	131 RE	No	34,425	9,000,000		"	30	1937	Open	18
	(D. & H.)	2519	7392	253	131 RE	No	34,425	3,000,000	"	"	65	Sept. 1939	"	1
	(D. & H.)	6566	Closures Only	98	131 RE	No	32,000	5,353,500	"	"	65-35	June - July 1937	"	19
	(D. & H.)	3168	" "	65	131 RE	No	34,425	11,860,000	"	"	60	1937	"	1
	(D. & H.)	4333	" "	53	131 RE	No	32,000	3,567,000	"	"	65	1937	"	None
	(D. & H.)	3273	" "	47	131 RE	No	34,425	16,969,738	"	"	60	1937	"	7
				2075										46
"C2" Thermit (Full Fusion)	(D.& R. G. W.)	4353	33298	1552	130 PS	No	36,500	10,000,000	"	"	40	Jan. - July 1943	Tunnel	10
	(Erie)	5577 (1)	5577	286	131 RE	No	36,000	23,000,000 .		"	40	Oct. 1943	"	None
"D" Electric Pressure Weld - - - - - - - - - -	(D. & H.)	6983	2693	70	131 RE	No	34,425	9,000,000		"	45	June - Sept. 1935	Open	2
	(D. & H.)	5953	17477	874	131 RE	No	34,425	9,000,000	"	"	30	1937	"	2
	(D. & H.)	6566	42768	1987	131 RE	No	32,000	3,353,500	"	"	65-35	June - July 1937	"	12
	(D. & H.)	4333	38544	1622	131 RE	No	32,000	3,567,000	"	"	65	1937	"	None
	(D. & H.)	3273	6547	513	131 RE	No	34,425	16,969,738	"	"	60	1937	"	1
	(D. & H.)	3168	21701	1142	131 RE	No	34,425	11,860,409	"	"	60	1937	"	1
	(D. & H.)	1401	13622	1069	131 RE	No	32,000	5,353,500	"	"	65	May 1939	"	1
				7277										19
"E" Gas Pressure Weld (Oxweld) - - - - - - - -	(C. of Ga.)	2574	2574	128	112 RE	No	32,500	11,250,000	"	"	30	May 1944	Tunnel	None
	(C. of Ga.)	1287	1287	64	112 RE	No	32,500	11,250,000	"	"	30	May 1944	"	None
				192										
	(G. N.)	6423	6423	328	112 RE	No	28,000	Not reported	"	"	25	1946	"	None
	(G. N.)	9612	21104	1082	115 RE	No	41,000	12,500,000	"	"	30	July 1949	"	None
	(G. N.)	1053	1053	54	115 RE	No	41,000	19,000,000	"	"	55	July 1949	"	None
	(G. N.)	3500	3500	178	115 RE	No	41,000	4,500,000	"	"	50-40	July 1949	"	None
	(G. N.)	3500	3500	178	115 RE	No	41,000	4,500,000	"	"	50-40	June 1949	"	None
	(G. N.)	1869	1869	94	115 RE	No	41,000	12,500,000	"	"	30	July 1949	"	None
				1914										
	(A. T. & S. F.)	3076	5607	284	112 RE	No	35,000	8,000,000	"	"	40	Aug. 1945	"	None
	(N.C. & St. L.)	2301	2301	116	131 RE	2 Pr.	29,000	22,000,000	"	"	25-15	Apr. 1947	"	None
	(B. & M.)	975	25397	1187	107	No	35,000	20,000,000	"	"	30	1942	"	None
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	"	[illegible]	[illegible]	"	[illegible]

Study B

Comparative Economies Obtained by Use of 155 PS, 133 RE and 100 PS Rail Based on 38,000,000 Gross Tons Annual Traffic and 1948 Costs

Comparative Investment Charges Per Mile

	155 PS	*133 RE*	*100 PS*
Life of rail	1,070,000,000 GT	760,000,000 GT	165,000,000 GT
Years	28 Years	20 Years	4.3 Years
Rail and fastenings	$29,582	$26,207	$18,544
Salvage value at end of first life cycle	17,687	15,453	12,518
Total depreciation	$11,895	$10,754	$ 6,026
Total cost to lay	$ 4,398	$ 3,773	$ 2,871
Cost of working (in excess of periodic rehabilitation)	5,083	4,376	2,448
Total cost to install	$ 9,481	$ 8,149	$ 5,319
Annual Carrying Charges per Mile:			
Installation	$ 339	$ 407	$ 1,237
Depreciation	424	538	1,401
Interest at 6 percent	1,775	1,572	1,113
Total annual carrying charges	$ 2,538	$ 2,517	$ 3,751

Comparative Annual Maintenance Per Mile

Spot Lining and Surfacing

155 PS —Man-Hours— 510 at $1.04 = $ 530
133 RE —Man-Hours— 850 at 1.04 = 884
100 PS —Man-Hours—1700 at 1.04 = 1,768

Periodic Rehabilitation—Working in Face

155 PS —Worked in 5 year cycles at $10,800 each = $2,314
133 RE —Worked in 3 year cycles at 9,250 each = 3,238
100 PS —Worked in 2 year cycles at 7,920 each = 3,684

Ties Required in Periodic Rehabilitation

155 PS —27 year life at $5.32 = 120 ties per year = $638
133 RE —25 year life at 5.32 = 130 ties per year = 692
100 PS —23 year life at 5.32 = 141 ties per year = 750

Ballast Required in Periodic Rehabilitation

155 PS —200 tons at $1.95 = $390 per cycle = $ 78
133 RE —200 tons at 1.95 = 390 per cycle = 130
100 PS —200 tons at 1.95 = 390 per cycle = 195

Maintenance—Summary	*155 PS*	*133 RE*	*100 PS*
Spot lining and surfacing	$ 530	$ 884	$ 1,768
Periodic rehabilitation	2,314	$3,238	$ 3,684
Ties required in periodic rehabilitation	638	692	750
Ballast required in periodic rehabilitation	78	130	195
Total	$3,560	$4,944	$ 6,397

Total Annual Cost

Annual carrying charges	$2,538	$2,517	$ 3,751
Annual maintneance cost	3,560	4,944	6,397
Grand Total	$6,098	$7,461	$10,148

Report on Assignment 6

Continuous Welded Rail

Collaborating with Committee 5

I. H. Schram (chairman, subcommittee), C. H. Blackman, T. A. Blair, B. Bristow, B. Chappell, C. J. Code, P. O. Ferris, H. S. Loeffler, R. F. Logan, R. R. Manion, Ray McBrian, E. H. McGovern, B. R. Meyers, R. J. Middleton, E. E. Oviatt, J. C. Ryan, A. P. Talbot, H. F. Whitmore, R. P. Winton.

This is a progress report submitted as information.

The usual reports are submitted, as they have been annually heretofore. They consist of a statement showing installations of continuous welded rail remaining in the track with the pertinent data in connection therewith; a summary statement of installations by different processes and failures therein; a statement of additional failures reported this year; and a short summary of complete installations, removals, etc., indicating one removal in the last year.

It will be noted that a considerable number of new installations has been made since the war years and that these new installations have continued through 1948 and, we are informed, through 1949, although only a few 1949 installations were reported in time to include them in these statements.

In addition to those indicated, a large number of short installations have been made to cover situations through station platforms, at road crossings or on bridges, etc.

All of these, for both long and short installations, have been of the gas pressure weld type and made with one type of equipment. No new installations of Thermit or electric pressure type welds of any great size have been reported since 1943. Many of these installations of former years have been removed.

The performance of the gas pressure weld has been excellent. Of the several installations in 1939 only one has showed failures, (5), or 1.3 percent of the joints. In the installations made in and subsequent to 1941 only 3 failures have occurred in the reported installations, or 0.017 percent of the joints. It is apparent that this type of weld is satisfactory and safe.

The economics of welded joints are fully discussed in the report on Assignment 4—Labor economics derived from continuous welded rail in special locations, of Committee 22—Economics of Railway Labor, Proceedings, Vol. 49, 1948, on page 139, and this phase of the subject is not being given further attention.

The features of this subject being handled by the Track committee are not completed and further discussions with that committee are continuing.

Summary of Installations of Continuous Welded Rail

	Installations	*Removals*	*Renewals*
"C-1" Thermit (type K)	8	0	0
"C-2" Thermit (full fusion)	1	1	0
"D" Electric pressure weld	7	0	0
"E" Gas pressure weld	50	0	0
Total installations	66		
Total removals		1	
Total renewals			0

Description of 1948 Service Test Installations

The report of the committee last year described the two service test installations of various types of joint bars for the new 115 and 132 RE rail sections. Subsequently, at the request of the Rail Joint Company an additional joint bar design of the long toe or angle type was added to each of the two installations. The service test sections of the 132 RE joint bars are located on the eastbound main track of the Atchison, Topeka & Santa Fe Railway, 100 miles west of Chicago. Each test section is ½ mile in length, all located on tangent track. The test installation includes the following different test sections:

Location V—132 RE, headfree, 36 in., 6–6–7⅛-in. new AREA punching, 6-hole bars, placed in August 1948.

Location W—132 RE, headfree, 36 in., 9–9⅛–9-in. punching, 4-hole bars, placed in August 1948.

Location X—132 RE, headfree, 36 in., 6½–6½–5⅛–6½–6½ in. old AREA punching, 6-hole bars, placed in August 1948.

Location Y—132 Rail Joint Co. K–42, headfree, 36 in., 6½–6½–5⅛–6½–6½ in. old AREA punching, 6-hole bars, placed in March 1949.

Location Z—132 Rail Joint Co. K–44, headfree, long toe design, 39 in., 6½–6½–5⅛–6½–6½ in. old AREA punching, 6-hole bars, placed in March 1949.

It will be observed from the above that this test installation for 132 RE rail includes a comparison of three different designs of joint bars, and in the case of the new AREA headfree joint bar includes three different bolt hole spacings. Fig. 1 shows the exact location of each test section, tied in to mile posts and highways, and includes the designation letter and description of each.

In October 1948 measurements were made of rail surface profile, joint camber and out-to-out distances of bars on Locations V, W and X to provide base measurements for determining the rate of rail and batter, joint droop, and fishing surface wear. Corresponding measurements were made at Locations Y and Z in May 1949 and October 1949, respectively. Stress measurements were also made on the bars of two joints for each location except Z in November 1948, to determine the dynamic stresses developed under regular traffic. The results obtained in these tests are presented below.

The test sections for the new 115 RE rail were installed on the west bound main track of the Chicago & North Western Railway near Sterling, Ill., 106 miles west of Chicago on the Omaha line. Each test section includes 100 joints and is approximately 2000 ft. long. Location EE, the long toe or angle bar design, was added in May 1949, the other sections having been placed in November 1948. This test installation now includes the following sections all on tangent track.

Location AA—115 RE headfree, 36 in., 9–9⅛ in. punching, 4-hole bars.

Location BB—115 RE headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.

Location CC—115 R. J. Co. K–22, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.

Location DD—115 R. J. Co. K–4, headfree, 36 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.

Location EE—115 R. J. Co. K–24, headfree, long toe design, 39 in., 6–6–7⅛–6–6 in. new AREA punching, 6-hole bars.

SUMMARY OF PROCESSES

Process	In Tunnels			In the open		
	Instal-lations	Welded Joints	Failures	Instal-lations	Welded Joints	Failures
"C-1" Thermit (type K)	1	506	1	7	2365	53
Removed						
Remaining	1	506	1	7	2365	53
"C-2" Thermit (full fusion)	2	1838	10			
Removed	1	286				
Remaining	1	1552	10			
"D" Electric pressure				7	7277	19
Removed						
Remaining				7	7277	19
"E" Gas Pressure Weld (Oxweld)	*24	7474		26	10704	8
Removed						
Remaining	*24	7474		26	10704	8

*Two installations, tunnel and open.

STATEMENT OF ADDITIONAL FAILURES

Railroad	Location	Process	Date Installed	Failures Previously Reported	Failures This Report	Total Failures
G. N.	Rexford, Mont.	"C1" Thermit	1937	4	3	7
D. & H.	Schenectady, N.Y.	"C1" Thermit	1937	8	10	18
D. & H.	Port Henry, N.Y.	"C1" Thermit	1937	11	8	19
D.&R.G.W.	Moffat tunnel, Colo.	"C2" Thermit	1943	6	4	10
D. & H.	Schenectady, N.Y.	"D" Elec. pressure	1935	1	1	2
D. & H.	Port Henry, N.Y.	"D" Elec. pressure	1937	6	6	12
N. Y. C.	Silver Creek, N.Y.	"E" Gas pressure	1948	0	1	1

Report on Assignment 7

Service Tests of Various Types of Joint Bars

T. A. Blair (chairman, subcommittee), J. B. Akers, H. B. Barry, W. J. Burton, E. E. Chapman, C. M. Chumley, C. J. Code, P. O. Ferris, R. L. Groover, S. R. Hursh, L. R. Lamport, E. E. Mayo, Ray McBrian, E. H. McGovern, R. A. Morrison, Embert Osland, R. E. Patterson, W. C. Perkins, J. C. Ryan, W. D. Simpson.

This is a progress report presented as information. The field work, analysis of data, and report of the measurements covered in this report were carried out by the Engineering Division research staff of the Association of American Railroads, under the general direction of G. M. Magee, research engineer, by Olaf Froseth, assistant track engineer, and M. F. Smucker, assistant electrical engineer, assisted by other staff members.

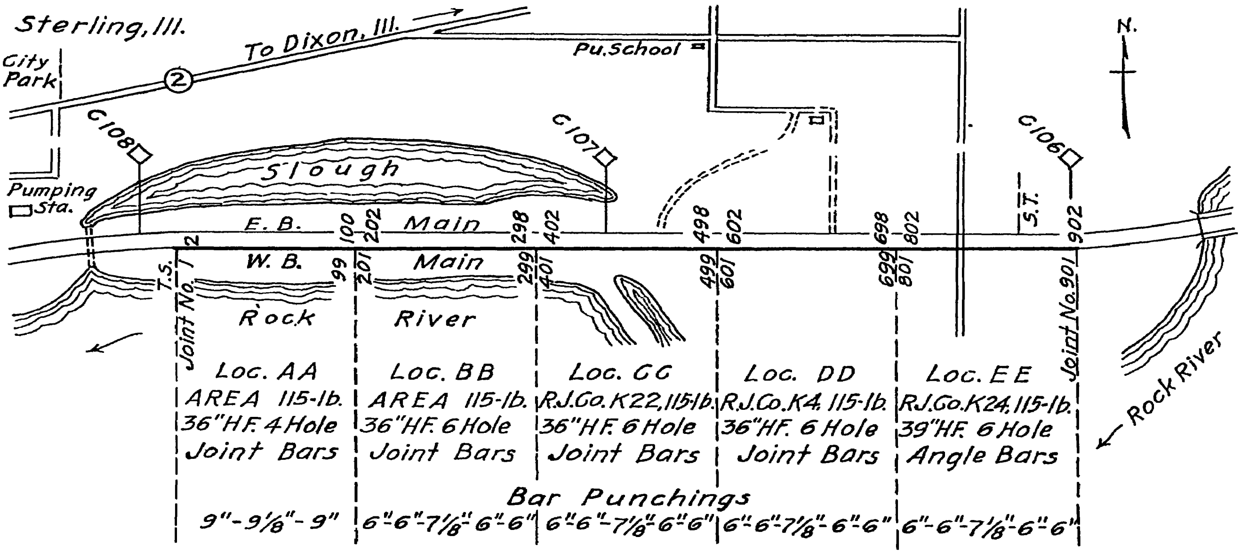
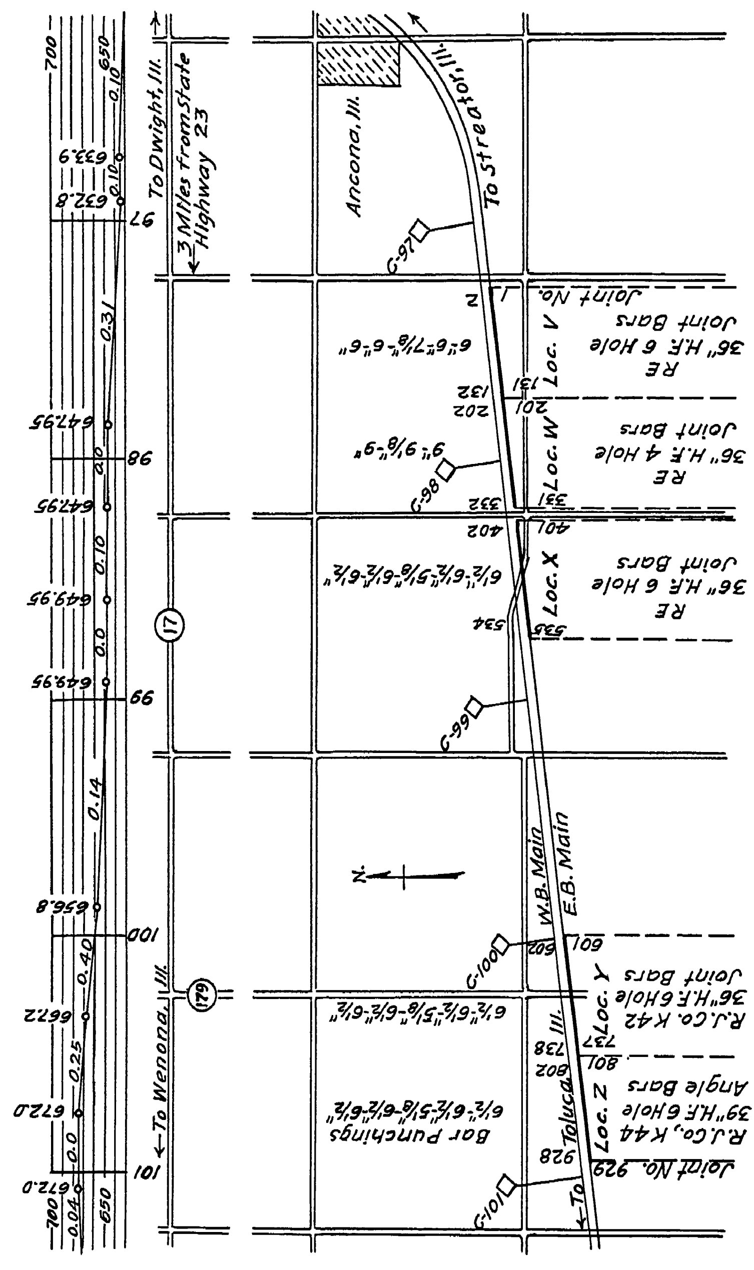
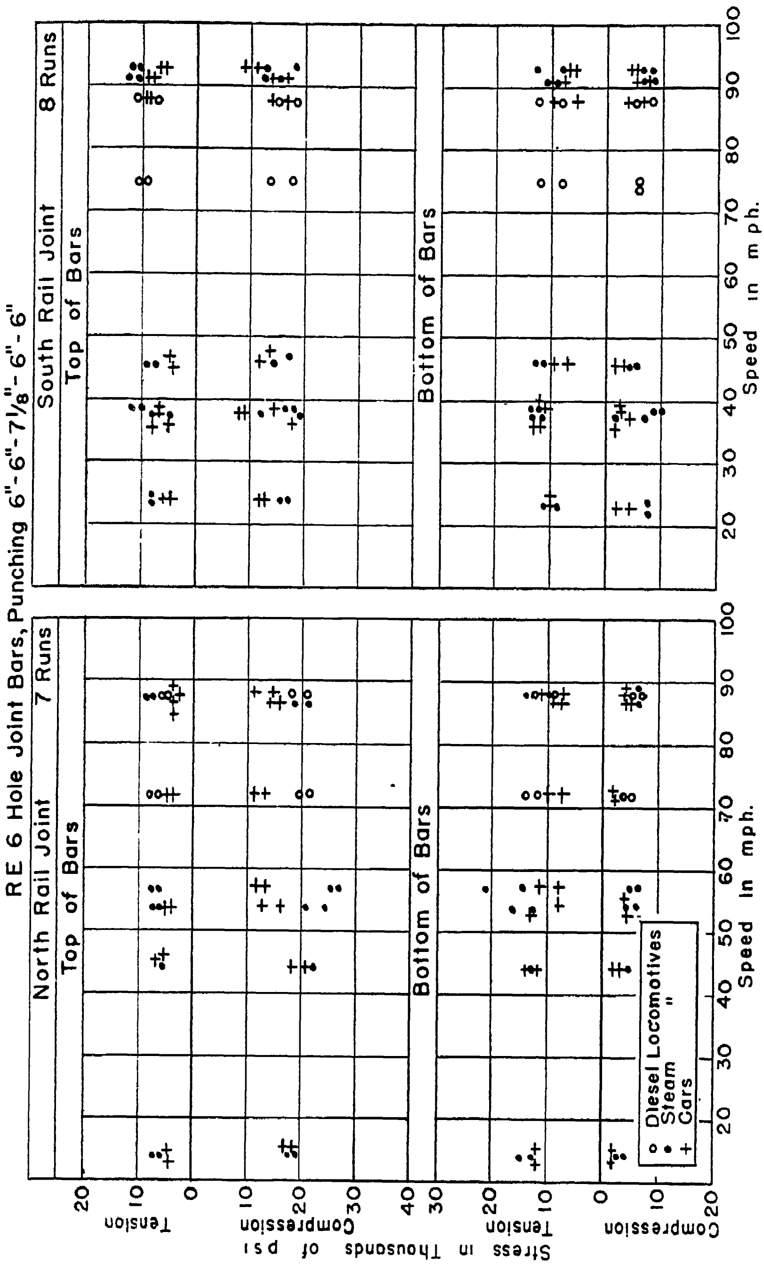


Fig. 2.—Service Test of Joint Bars, C. & N. W. Ry., at Sterling, Ill. 115 RE rail laid in November 1948; R. J. Co. K 24; angle bars in Location E E installed in May 1949.



Notes: 132-lb. rail in E. B. Main Track laid in August 1948.
R.J. Co. K42 Bars in Loc. Y and K44 in Loc. Z installed in March 1949.

Fig. 1.—Service Test of Joint Bars, A. T. & S. F. Ry. near Streator, Ill.



Note: Both Gage and Field Side Stresses Shown.
Position of SR 4 Strain Gages Shown on Fig. 11.

Fig. 4.—Maximum Dynamic Stresses at Middle of 132-Lb. 36-In. H. F. Joint Bars, Location V, A. T. & S. F. Ry.

The designation letters for Locations AA to DD inclusive are the reverse of the order given in the report last year. This change was made after Location EE was added to have the sections in alphabetical order in the track.

It will be noted that the above includes four different designs of joint bars and also includes for the new 115 AREA headfree design a test section with the new AREA punching and a test section with a four-hole punching for a 36-in. length bar. Fig. 2 is a map of the track at the test locations and shows mile posts, highways, designation letters, and joint bar description relative to each test section. Measurements of rail surface profile, joint camber and out-to-out distances of bars were made in May 1949. In addition, stress measurements were taken on a number of joint bars of each design and the results of these will be included in next year's report.

Dynamic Stresses Developed in Joint Bars under Traffic—Santa Fe 132 RE Test

No measurements of the range of bending stress at the top and bottom extreme fibers of joint bars had been made with the SR-4 type electrical wire resistance gages prior to the tests described in this report. Measurements of joint bar stresses had been made as described in the reports of the Committee on Stresses in Railroad Track under the direction of Dr. A. N. Talbot. These earlier measurements were made with the magnetic type gages which, due to their weight and method of attachment to the bar, are somewhat affected by the impact effects from the joint gap. Also, the SR-4 gage is capable of measuring the stress at a much shorter gage length and directly at the surface. Accordingly, it was considered desirable in connection with the service test installation of the new joint bar designs to obtain measurements with the SR-4 type gages of stresses developed under traffic. Because of the lack of time, measurements were made only at two joints for the V, W, X and Y locations. At the time of the measurements the test bars had not yet been installed at the Y and Z locations. However, the bars were available for Location Y so after the two joints were tested at Location X, the bars were removed and replaced with bars of the Y type at the two test joints. This was possible because the drilling was the same. This provided a comparative test of the Rail Joint Co. K-42 design and the AREA design on the same rail ends and with exactly the same conditions of tie support.

The maximum bending moment in the joint bar occurs, of course, at midlength, so most of the stress measurements were made with the gages placed at mid-length of the bars. Fig. 11 shows the position on the cross section at which the gages were located. Gage position 2 was at the top extreme fiber of the joint bar. Gage position 5 was at the outer part of the base of the bar near the bottom, the nearest position to the lower extreme fiber that it was practical to place the gage. Gages were placed to

(text continued on page 580)

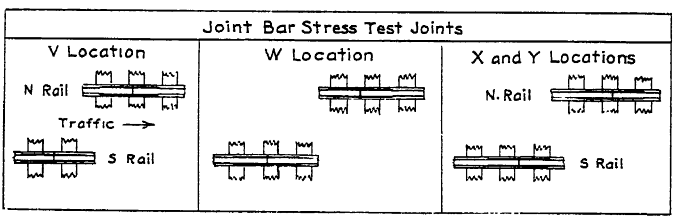
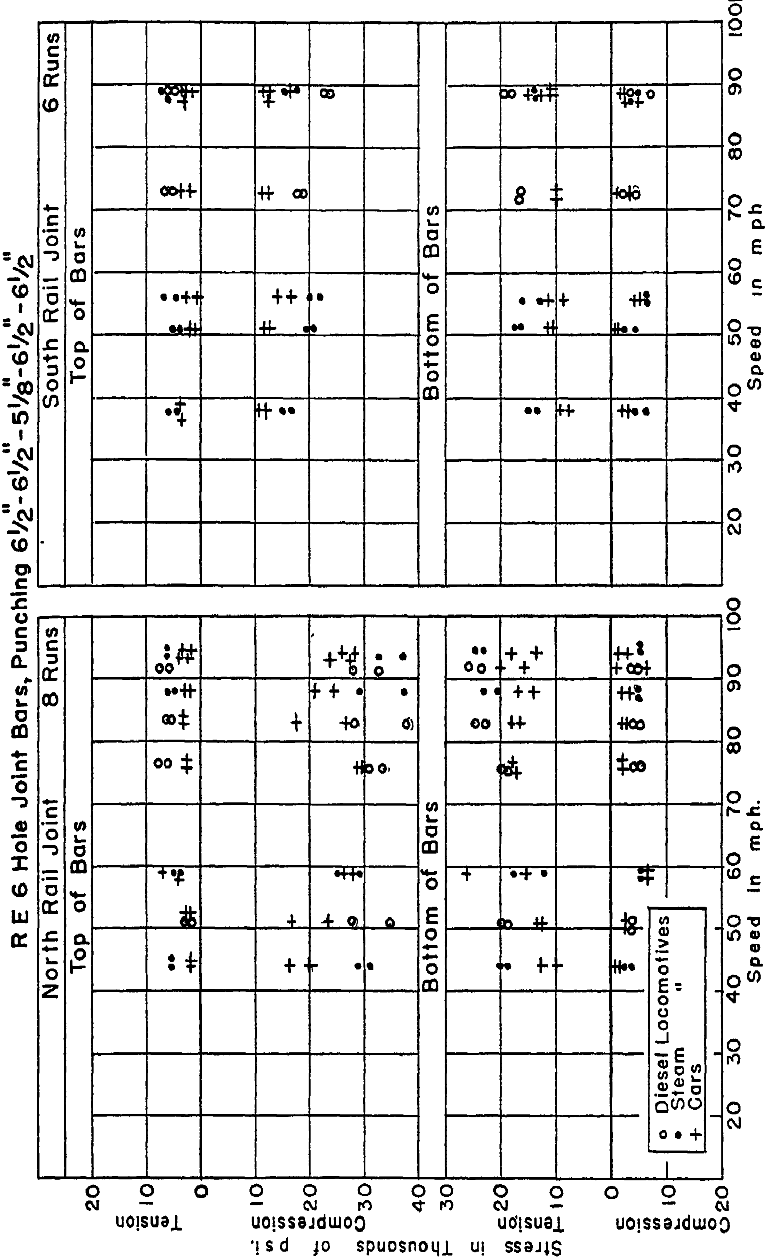
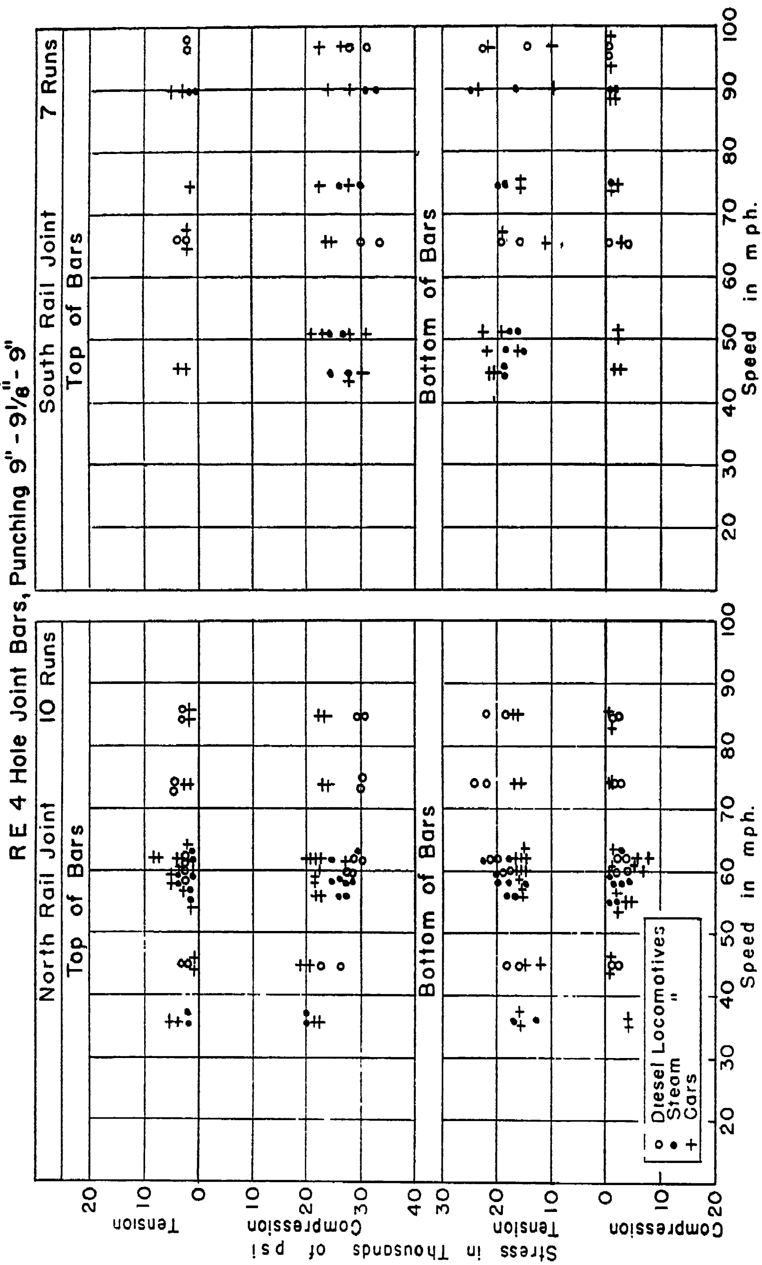


Fig. 3.—Location of Test Joints with Respect to Cross Ties, A. T. & S. F. Ry.



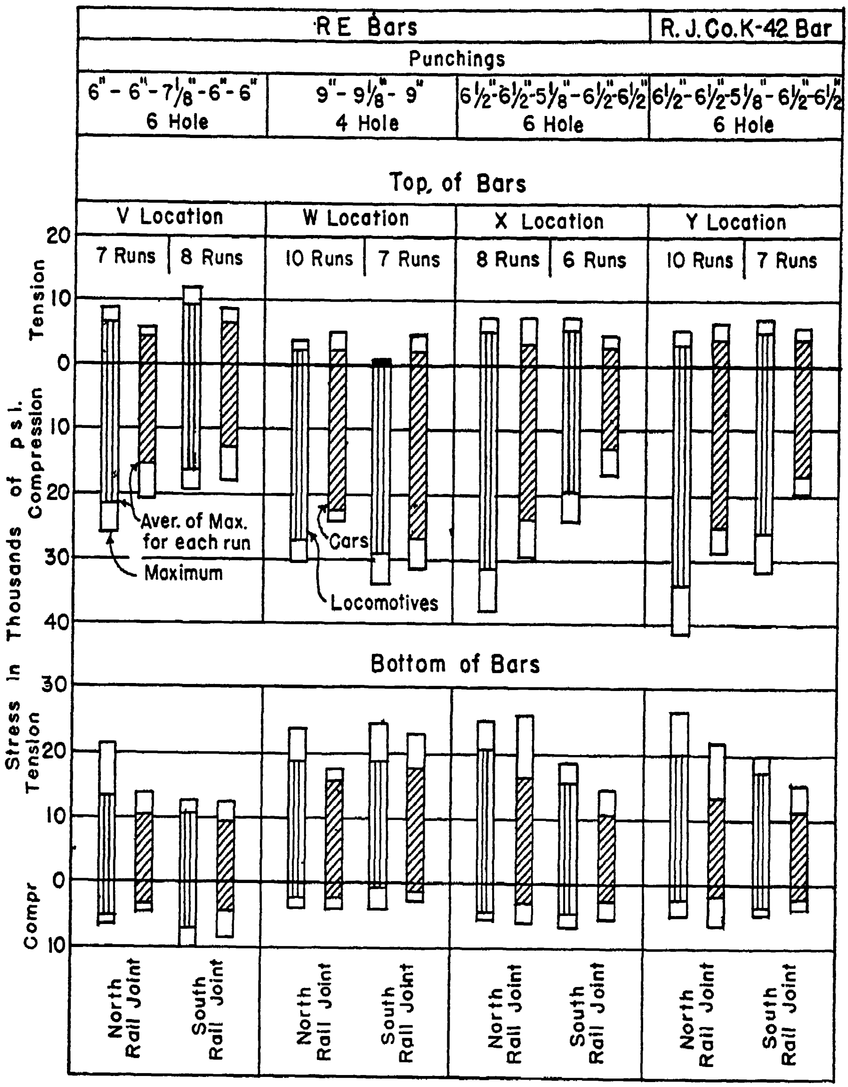
Note: Both Gage and *Field* Side Stresses Shown.
Position of SR 4 Strain Gages Shown on Fig. 11.

Fig. 6.—Maximum Dynamic Stresses at Middle of 132-Lb. 36-In. H. F. Joint Bars, Location X, A. T. & S. F. Ry.



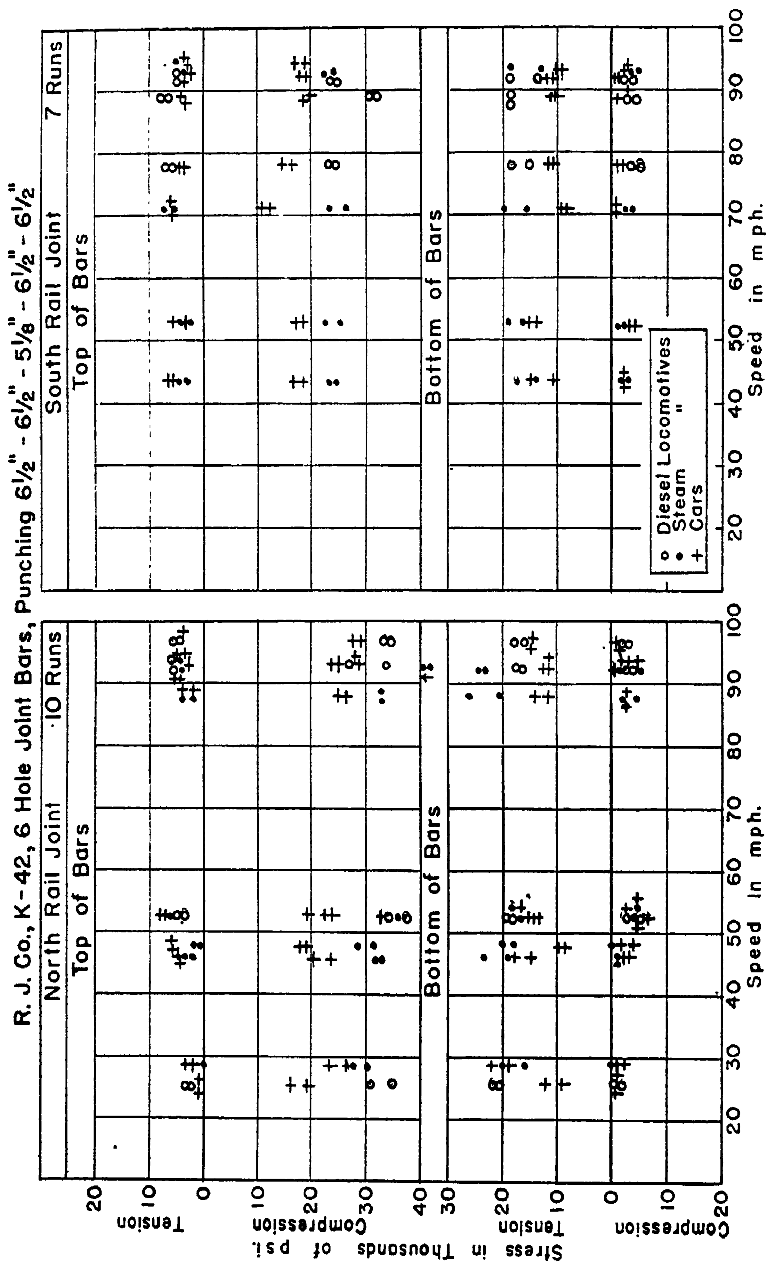
Note· Both Gage and Field Side Stresses Shown.
Position of SR 4 Strain Gages Shown on Fig. 11.

Fig. 5.—Maximum Dynamic Stresses at Middle of 132-Lb. 36-In. H. F. Joint Bars, Location W, A. T. & S. F. Ry.



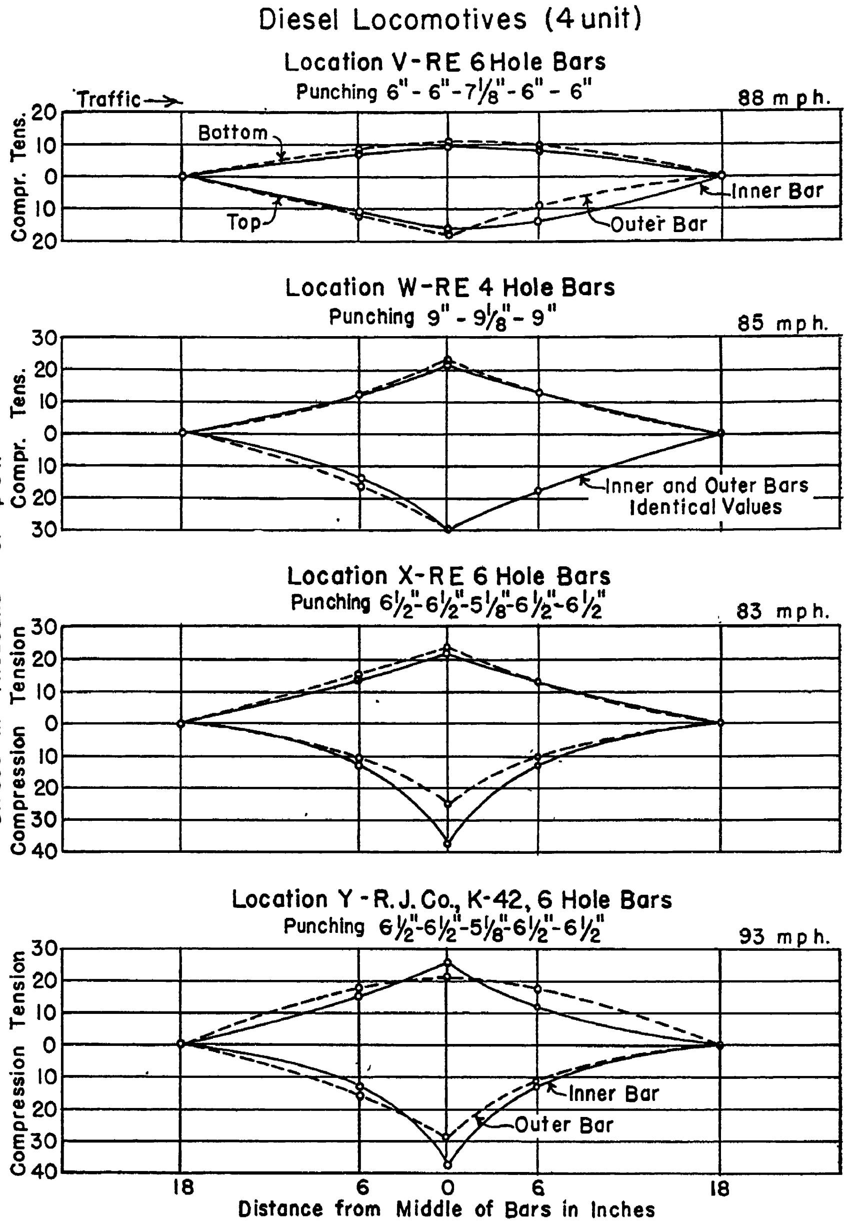
Note: Average stresses are the mean of Gage and Field side measurements
Position of SR 4 Strain Gages shown on Fig. 11.

Fig. 8. Dynamic Stresses at Middle of 132-lb. 36-in. H. F. Joint Bars, A.T. & S.F. Ry.



Note: Both Gage and Field Side Stresses Shown.
Position of SR 4 Strain Gages Shown on Fig. 11.

Fig. 7.—Maximum Dynamic Stresses at Middle of 132-Lb. 36-In. H. F. Joint Bars, Location Y, A. T. & S. F. Ry.



Note: Stresses measured under Front Wheels of Rear Truck of Second Unit.

Fig. 9.—Instantaneous Stresses at Top and Bottom of 132-Lb. 36-In. Joint Bars, A. T. & S. F. Ry.

(text continued from page 574)
measure bending stress parallel to the length of the bar. Figs. 4 to 7, incl., show the maximum tension and compression bending stresses developed at both the top and bottom of the joint bar for the various test runs for the different joint bar designs and bolt spacings. As would be expected for the top of the bars, the tension stresses are less than one-half the compression stresses, and at the bottom of the bars the compression stresses are less than one-half the tension stresses. The stress values are shown with respect to train speed, but there appears to be no significant relation between bar stress and the speed of train movement.

In Fig. 8 is shown a comparison of the average maximum stresses and single maximum stress obtained at each of the two joints of the four test locations. Inasmuch as only two joints of each type were included and previous tests have shown that a considerable variation in bending stresses from joint to joint is to be expected depending upon the condition of the support, too much reliance should not be placed upon these values in comparing the merits of joint bar design and bolt hole spacing. However, the diagram does serve to give an idea of the range of bending stresses developed in the bar and indicates at least that there is no important difference in bending moment as a result of the various bolt hole spacings used, nor does there appear to be any outstanding difference in the characteristics of the bending stresses between the two designs of joint bars included.

The relation between tension and compression stresses is informative of the effectiveness of the tie support at the joint. For example, for both joints at the V-location the bending stresses for positive moment (wheel over the joint gap) are about twice the stresses for negative moment (joint between wheels). This indicates that the joints are well supported with little play between the rail and tie. However, for both joints at Location W the negative moment developed was quite small, indicating that there was some play (swinging condition) at these joints. The number of joints tested was too few to conclude that this was attributable to the use of only four bolts in the joint bars. If this is true, the annual measurements of joint droop will so indicate during service use.

It is particularly interesting to compare the range of bending stresses developed under service conditions, as indicated by Fig. 8, with the bending stresses to which the joint bars are subjected in the accelerated rolling load tests at the University of Illinois. A fully assembled rail joint is used in the rolling-load tests and by repeated loading the joint is subjected to a positive bending moment for the 132 RE section of 500,000 in.-lb. with a negative bending moment of 250,000 in.-lb. The positive bending moment occurs with the wheel load directly over the joint gap and the negative bending moment occurs when the joint is flexed upward, as between wheels. For the maximum positive bending moment developed in the machine the calculated bending stress at gage location 2 is 44,000 psi. compression and at gage location 5 is 38,000 psi. tension for the AREA design bar. The results recorded in Fig. 8 for AREA design bars with the new bolt spacing (Location V) show an average maximum compression stress at the top of the bars of 22,000 psi., and an average maximum tension stress at the bottom of the bars of 14,000 psi. The values for average maximum stress are given rather than the single maximum value because it seems certain that only the average maximum stresses would be repeated with sufficient frequency to produce a fatigue failure in any reasonable service period. The actual service stresses, therefore, with respect to development of fatigue failure in these tests were found to be only half as great as the range of stress to which the joint bars are subjected in the accelerated fatigue tests in the rolling-load machines at the University of Illinois.

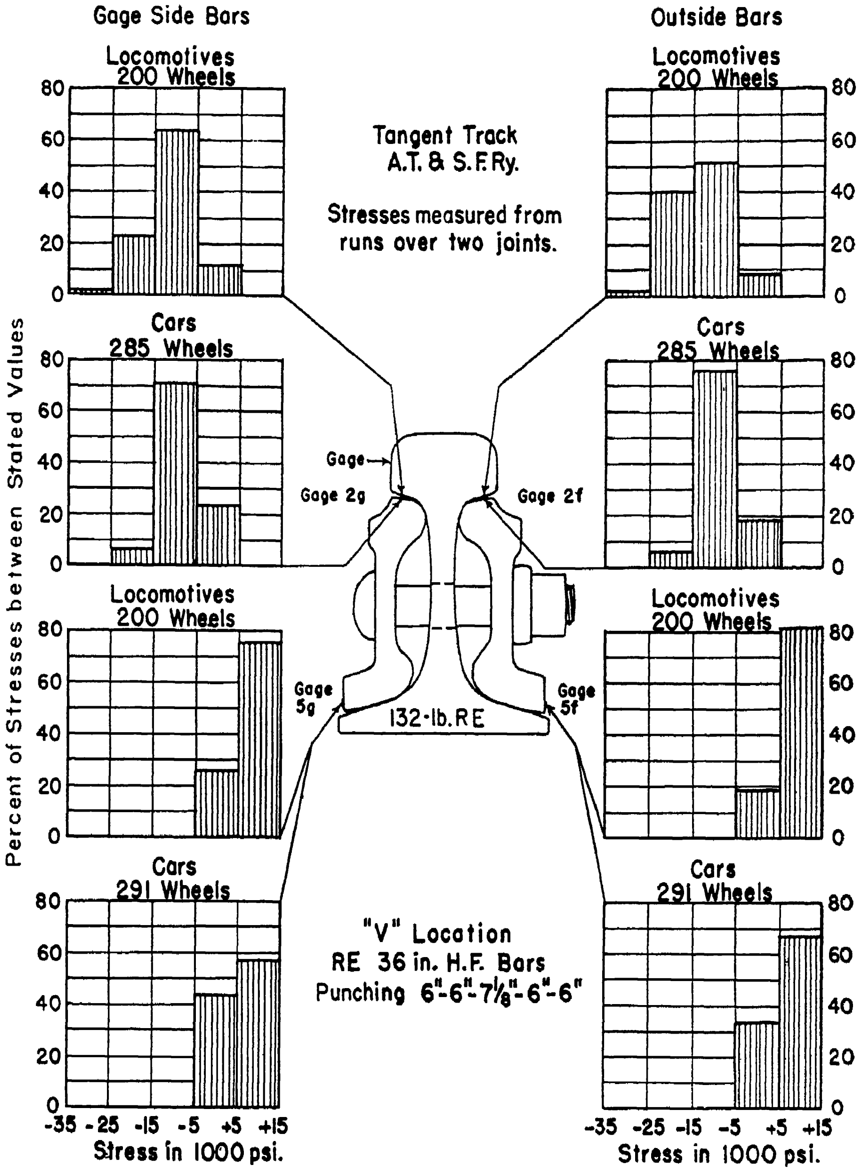
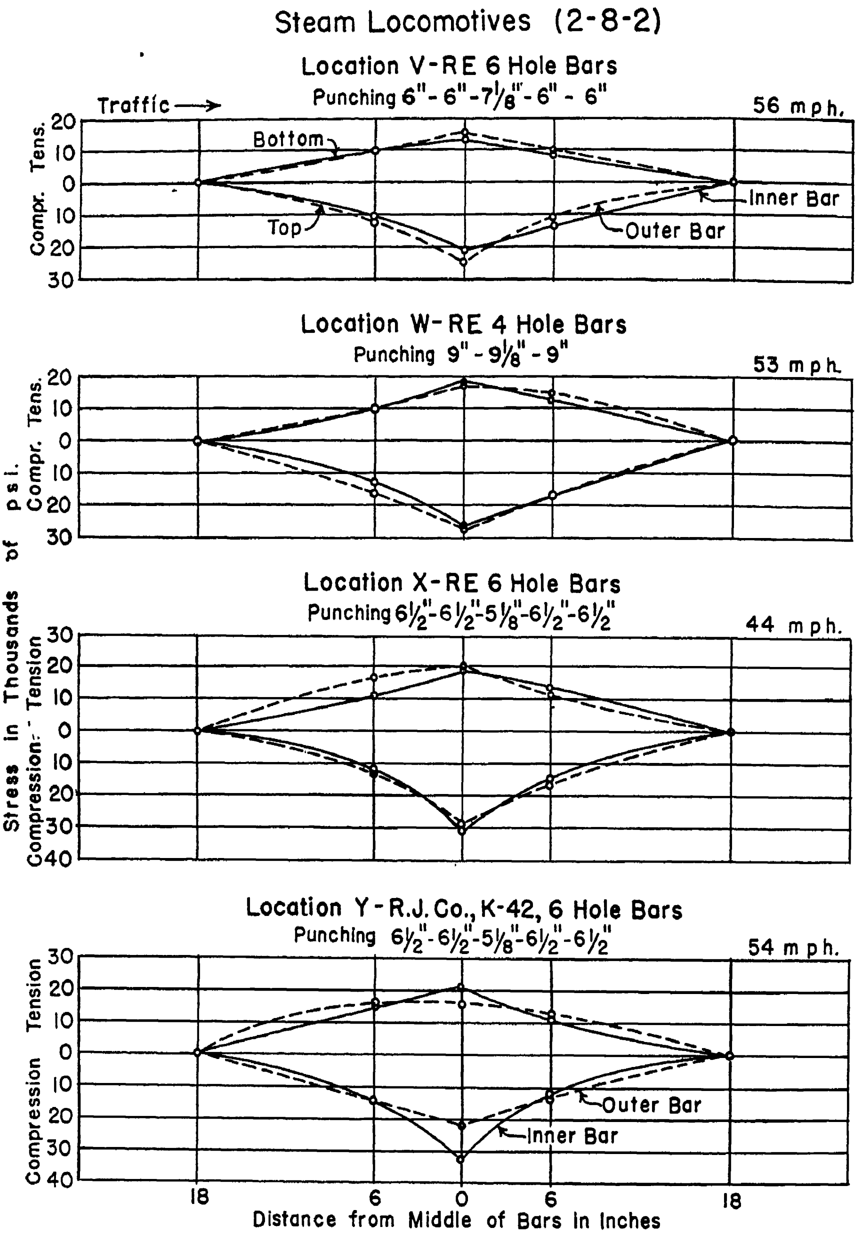
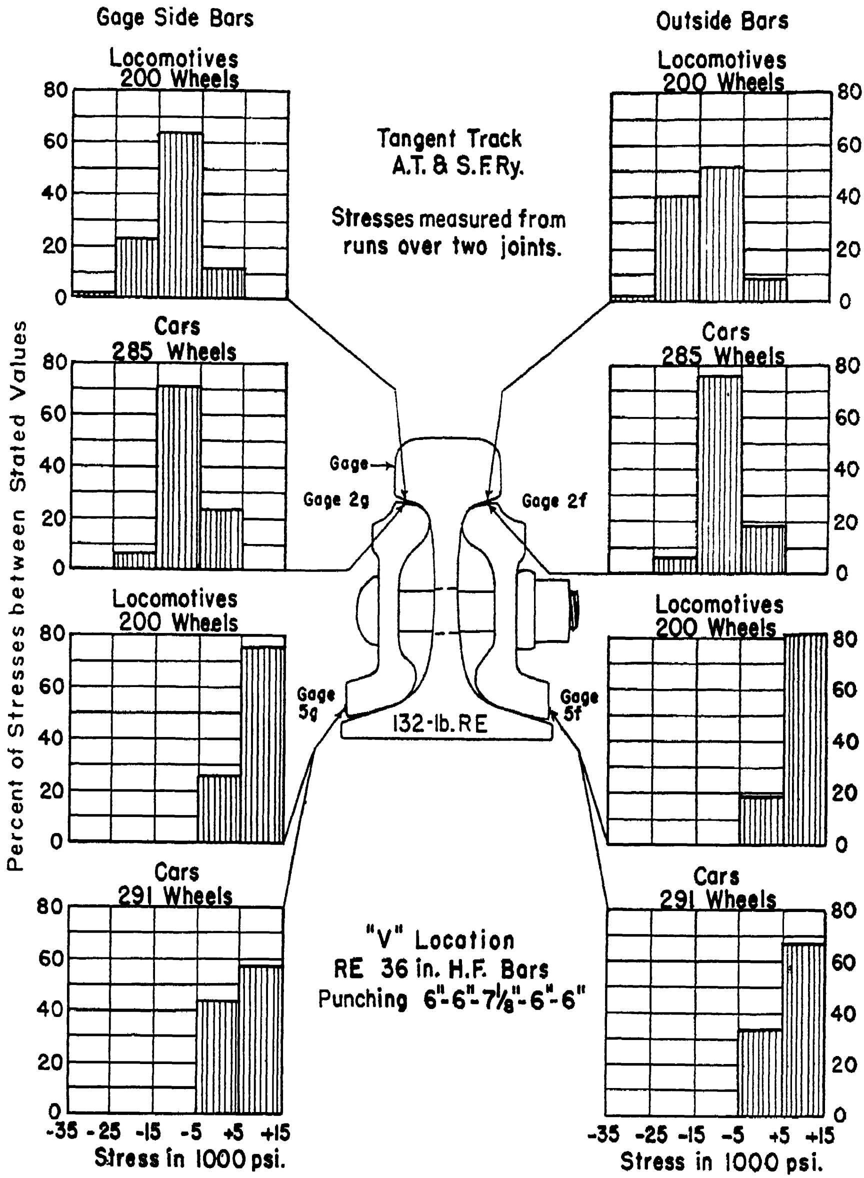


Fig. 11.—Frequency of Occurrence of Stresses at Middle of Joint Bars.



Note: Stresses measured under Trailer Wheels.

Fig. 10.—Instantaneous Stresses at Top and Bottom of 132-Lb. 36-In. Joint Bars, A. T. & S F. Ry.



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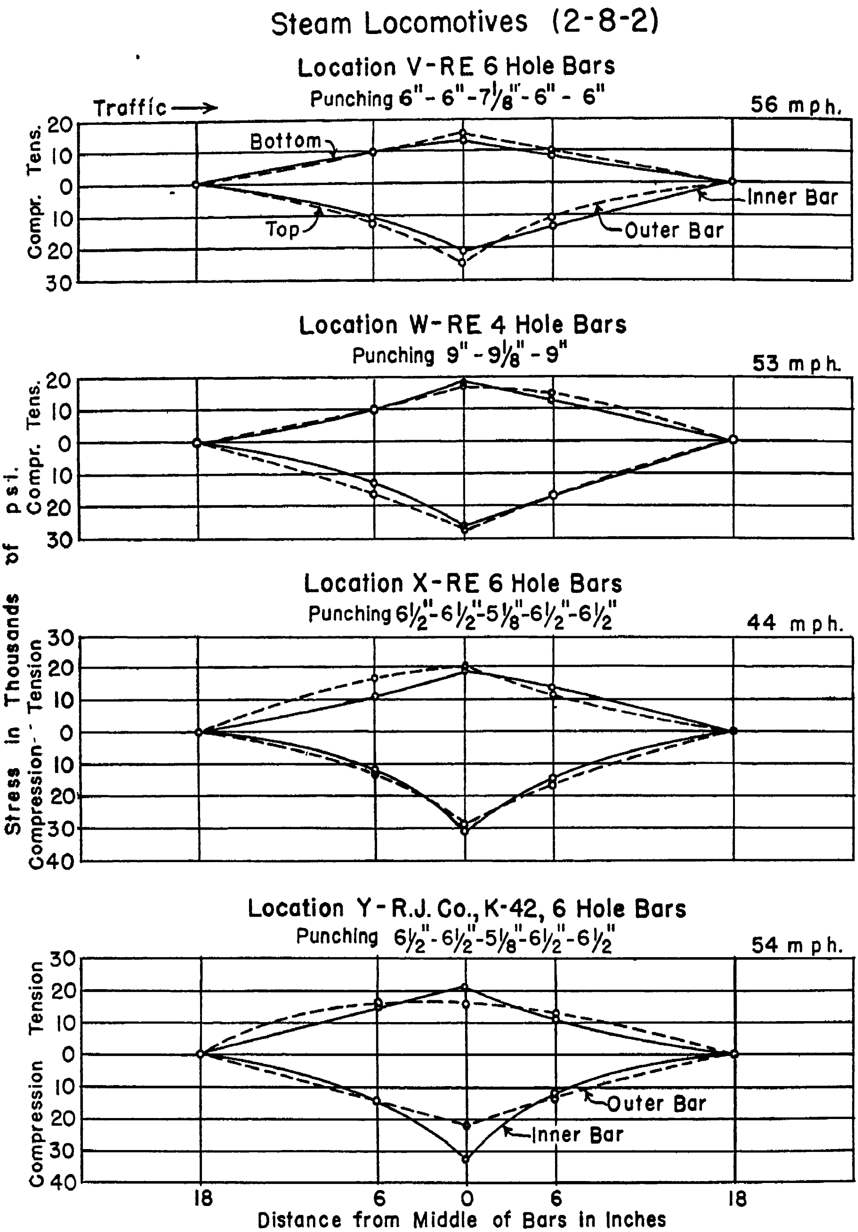

Note: Stresses measured under Trailer Wheels.

Fig. 10.—Instantaneous Stresses at Top and Bottom of 132-Lb. 36-In. Joint Bars, A. T. & S F. Ry.

Report on Assignment 8

Joint Bar Wear and Failures; Revision of Design and Specifications for New Bars and Bars for Maintenance Repairs

E. E. Chapman (chairman, subcommittee), J. B. Akers, H. B. Barry, T. A. Blair, W. J. Burton, C. M. Chumley, C. J. Code, L. S. Crane, P. O. Ferris, R. L. Groover, S. R. Hursh, L. R. Lamport, E. E. Mayo, Ray McBrian, E. H. McGovern, R. A. Morrison, Embert Osland, R. E. Patterson, W. C. Perkins, J. C. Ryan, W. D. Simpson.

This is a progress report, submitted as information.

A progress report of the principal work on the assignment during the past year has been the continuation of the rolling-load tests of joint bars being conducted at the University of Illinois under the direction of R. S. Jensen. The result of these tests is submitted in Appendix 8-a.

Appendix 8-a

Eighth Progress Report of the Rolling Load Tests of Joint Bars

By R. S. Jensen

Special Research Assistant Professor of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This report covers tests of joint bars conducted during the past year in the Talbot Laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association Committee on Rail under Assignment 8—Joint bar wear and failures; revision of design and specifications for new bars and bars for maintenance repairs. E. E. Chapman, mechanical assistant to assistant to vice-president, Atchison, Topeka & Santa Fe Railway, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Acknowledgment is made of the services of Lewis Franklin and Elmer Hunt, mechanicians in the Talbot Laboratory shops, and Frank Perkins, student test assistant.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-in. stroke rolling machines similar to the one described in the AREA Proceedings, Vol. 40, 1939, page 649. The dimensions of the test joint and method of loading are described in the Proceedings, Vol. 44, 1943, page 587. In all tests the maximum bar bending stresses are obtained with the wheel load at the joint gap and are 50 percent in value and reversed in sign with the wheel load at the cantilever end of the stroke. The criterion for bar failure is taken to be the number of cycles of loading to propogate a fatigue crack to ½ of the bar height.

Results of Rolling Load Tests

Twenty-four tests on joint bars have been completed since the last annual report was published; these include 12 tests on 133 RE head contact 36-in. bars, and 12 tests on 115 RE headfree 36-in. bars. Table 1 lists the chemical analyses and Table 2 the physical properties of heats for the 133 RE and 115 RE bars as supplied by the manufacturers.

Distribution of Bending Stress along the Joint Bars

Tests were made and reported by the Committee on Stresses in Railroad Track of the distribution of stress along the length of the joint bar. These studies pointed out that the pattern of stress distribution was indicative of the location at which the resultant pressures were applied between the fishing surfaces of the rail and joint bar. (See AREA Proceedings Vol. 35, 1934, page 251.)

The stress at the mid-length of the bar is a maximum and at the end of the bar is, of course, zero. If the stress distribution follows a straight line between these points, this indicates that the full length of the bar is effective in developing the bending moment for supporting the rail joint. If the stress distribution pattern is concave, this indicates that the middle portion of the joint bar is developing most of the bending moment. If the stress distribution is convex, this indicates that the bending moment is being developed at the ends of the bar. A straight line distribution is most desirable because this will maintain, for a given bending moment, the bearing pressures at the minimum value and may be expected to give the least rate of wear and longest joint bar life.

To develop information on the stress distribution along the length of the bar measurements were made with gages also placed at the top and bottom of the bar, 6 in. each way from mid-length. Simultaneous stress readings for maximum moment developed at the mid-length of the bar, therefore, give a picture of the stress distribution along the bar length. Results obtained from these measurements are shown in Fig. 9 for maximum stresses developed under diesel locomotives, and in Fig. 10 for maximum stresses developed under steam locomotives. Each diagram shows the results obtained for one joint for each of the four test sections included in the stress measurements. Generally speaking, the stress patterns as indicated by these two diagrams are quite satisfactory. The pattern for both the AREA design bars with only the four bolts and also the new AREA bolt spacing for the 6-hole bars is especially good.

Frequency of Joint Bar Stresses in Service

To determine information on the frequency with which stresses of any given magnitude might be expected to be developed in track under regular train operation, the analysis shown in Fig. 11 has been prepared. This figure includes the stresses developed at the top and bottom of the bars on both the gage and field sides, and shows the frequency for locomotives and cars separately. Maximum stresses are, of course, developed under the locomotives, and for the top of the bar the principal stress range is seen to be 5000 psi. tension to 25,000 psi. compression. At the bottom of the bar the corresponding stress range is from 5000 psi. compression to 15,000 psi. tension. These results are for the AREA design of bar with the new bolt spacing. The developed stresses as indicated by this diagram are well within the fatigue strength of the joint bars as indicated by the rolling-load tests.

Conclusions

The results obtained in these tests on tangent track indicate that the stresses developed in service in the new AREA headfree design and the Rail Joint Co. K-42 design of joint bars for 132 RE rail are well within the fatigue strength as determined by laboratory tests. It may be expected that the stresses will be higher on curved track, but the reserve appears sufficient to give assurance that these designs of joint bar will give satisfactory service from the standpoint of the development of fatigue failures.

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Magnaflux examination after testing revealed additional cracks on eight of the failed bars and seven of the companion bars. These cracks, which ranged in length from 1/8 in. to 7/8 in., were for the most part on the upper surfaces of the bars in the gouges caused by the rail ends, or in areas of heavy bearing or galling near the center of the bar.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed inward from 0.005 to 0.045 in. in elastic bending measured on the upper flanges. Elastic inward bending on the lower flanges ranged from 0.010 to 0.061 in.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges of the bars had moved inward from 0.013 in. to 0.055 in. at the center of bar length and from 0.005 in. to 0.038 in. at the ends. At the same time the upper flanges had moved inward at the center from 0.002 in. to 0.029 in. and at the ends from 0.002 in. to 0.015 in.

Fig. 1 shows three of the fatigue failures of the 133 RE bars.

Micrographs, taken on specimens from all failed bars, showed decarburized bar surfaces to various depths up to 0.022 in.

Rolling Load Tests of 115 RE Headfree Bars

Results of the 12 tests on joints with the 115 RE Headfree 36-in. bars are given in Table 3. Rail ends for these joints were hot sawed and milled by the manufacturer, and profiles of the rail fishing surfaces showed practically no rail end distortion. The average cycles for failure for these 12 tests was 1,462,450, with 5 of the joints running to 2,000,000 cycles with no failure. Three bar failures were from the top surface and four were from the base. On six of the failed bars the cracks progressed to bolt holes, four to oval holes and two to round holes. Examination after sawing halfway through the bars to complete the fractures revealed fatigue areas at five of the bolt holes extending in height from 1/8 in. to 5/8 in.

Fig. 2 shows fatigue failures of three of the 115 RE bars.

Magnaflux examination revealed additional cracks on the top surface of all the failed bars and companion bars. The cracks which appeared in the gouges caused by the rail ends varied in length from 1/4 in. to 3/4 in. In addition, from 12 to 20 small cracks from 1/8 in. to 3/8 in. in length were observed over the central 2 1/2 in. outside the bearing areas on the top surfaces of all except two of the bars. The two bars which did not show these small cracks were 175N and 181S, companion bars in the joints which failed at approximately 1/2 million cycles. Fig. 3 shows the top surface of bar 180N with numerous small cracks outlined by magnaflux, which is typical of these bars after a million cycles of testing.

Lateral deflection reading indicated that these bars pulled in at the center 0.002 to 0.016 in. in elastic bending measured on the upper flanges with an average of 0.005 in. Inward elastic bending for lower flanges was greater for most bars, ranging from 0.002 to 0.024 in. with an average of 0.012 in.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges had moved inward from 0.031 to 0.044 in. at the center of bar length, with an average of 0.039 in. and from 0.002 to 0.025 in. at the ends with an average of 0.015 in. The upper flanges moved inward at the center of bar length 0.003 in. to 0.018 in. with an average of 0.009 in. and at the ends the movement ranged from 0.012 in. inward to 0.005 in. outward with an average of 0.001 in. outward.

In addition, three tests have been made on 131 K4 headfree 36-in. angle bars as part of a total contemplated test program of 12 joints of this type; the results of these three tests will be reported when the series has been completed.

Data on these 24 joints are tabulated in Table 3.

Hardness Tests on Joint Bars

Both Brinell and Rockwell B hardness readings were taken on upper and lower fishing surfaces of all bars before testing. For the 133-lb. bars, the Brinell hardness ranged from 205 to 324 with 75 percent of the hardness readings falling between 250 and 300 Brinell. The average of all Brinell readings was 276 while the Rockwell B readings converted to Equivalent Brinell were 45 points lower on the average, denoting some decarburization of the bar surfaces.

Brinells for the 115-lb. bars ranged from 199 to 262 with 93 percent falling between 200 and 250. Equivalent Brinell from Rockwell B readings averaged 51 points lower for these bars.

TABLE 1.—CHEMICAL ANALYSES OF JOINT BARS

Bar Type	Length In.	Heat No.	Serial No.	Chemical Composition C	Mn	P	S	Si
133 RE F B	36	02E 120	19	.44	.71	.015	.027	------
133 RE F B	36	16E 140	20	.49	.79	.007	.040	------
133 RE F B	36	12E 216	27	.53	.75	.009	.029	------
133 RE F B	36	07E 229	28	.53	.75	.013	.040	------
115 RE H F	36	8500	6	.45	.64	.011	.036	0.11

TABLE 2.—PHYSICAL PROPERTIES OF JOINT BARS

Bar Type	Serial No.	Tensile Strength Psi.	Yield Point Psi.	Reduction of Area Percent	Elongation 2 in G L Percent
133 RE F B	19	128, 300	80280	37.3	15.1
133 RE F B	20	136, 100	88480	44.1	15.9
133 RE F B	27	138, 800	88290	39.1	15.2
133 RE F B	28	135, 800	86880	46.3	16.7
115 RE H F	6	119, 100	75530	46.2	21.5

Rolling Load Tests of 133 RE Head Contact Bars

Results of 12 tests of 133 RE bars are given in Table 3. In four of the tests, both bars of the joint failed, and in one test the broken bar exhibited fatigue areas on both the top and base, which is unusual. Of the 16 failed bars, 10 started from the base, 5 from the top and one from both top and base. On three bars the base breaks extended to bolt holes; however, no fatigue areas occurred at the vicinity of the holes. Five of the bars broke completely through before the machine automatically stopped.

The average of the cycles for failure for the 12 tests was 509,200. This compares with an average of 523,060 cycles for 12 tests of 132 K42 bars, and an average of 794,090 cycles for 12 tests of 132 AREA bars made last year.

TABLE 3.—Continued

Joint No.	Cycles for Failure	Bar Failure N=North S=South	Surface Hardness Failed Bar B H N	Surface Hardness Equivalent B H N* from Rockwell B	Depth of Decarb From Micrograph in.	Rail Ends H=Hot Sawed C=Cold Sawed	Pinching on Failed Bar in Top	Pinching on Failed Bar in Base
		Bars: 115 RE 36-in. Headfree—Hole Spacing 7⅛ in., 6 in., 6 in. Serial 6						
174	2, 000, 000	No failure	N–213	165	.017	H—Milled	000	000
			S–213	156	.009		000	000
175	650, 100	S. top—rail end	213	153	.024	H—Milled	000	000
176	998, 000	N. top—to bolt hole	213	172	.020	H—Milled	000	000
177	1, 449, 700	N. top—to bolt hole	205	169	.017	H—Milled	000	000
178	2, 000, 000	No failure	N–207	172	.014	H—Milled	.001	.003
			S–217	176	.007		000	000
179	2, 000, 000	No failure	N–205	156	.010	H—Milled	000	000
			S–218	165	.006		000	000
180	1, 462, 700	S. base to bolt hole	209	190	.018	H—Milled	000	000
181	424, 400	N. base to bolt hole	234	162	.016	H—Milled	000	000
182	1, 036, 200	N. base to bolt hole	231	159	.019	H—Milled	000	000
183	2, 000, 000	No failure	N–231	200	.013	H—Milled	000	.001
			S–236	172	.014	H—Milled	000	000
184	1, 528, 400	N. base to bolt hole	236	159	.014	H—Milled	000	.001
185	2, 000, 000	No failure	N–203	162	.014	H—Milled	000	000
			S–203	165	.013	H—Milled	000	.001
	1, 462, 450	Average						

*Equivalent BHN is average of 5 Rockwell B readings converted to Brinell.

TABLE 3.—ROLLING-LOAD TESTS ON JOINT BARS

Maximum positive bending moment: 55,500-lb. load—50,000 in.-lb. for 133-lb. bars.
Maximum positive bending moment: 44,400-lb. load—400,000 in.-lb. for 115-lb. bars.
Maximum negative bending moment is 50 percent of positive moment
Bolt Tension: 15,000 lb. Bolts 1⅛ in. and 1 in. dia., heat treated, prestressed

Joint No.	*Cycles for Failure*	*Bar Failure* *N=North* *S=South*	*Surface Hardness Failed Bar B H N*	*Surface Hardness Equivalent B H N* from Rockwell B*	*Depth of Decarb From Micrograph in.*	*Rail Ends H=Hot Sawed C=Cold Sawed*	*Pinching on Failed Bar in.* *Top*	*Pinching on Failed Bar in.* *Base*
		Bars: 133 RE 36-in. Head Contact Bars Serial 19, 20, 27, 28						
156	250,000	Both top—rail ends	N-216	185	.022	H	000	000
			S-205	176	.008		000	000
157	288,800	S. top and base—rail end	Top-228	172	.017	H	.012	.011
			Base-252	240	.005			
158	237,200	Both base N—to bolt hole	N-271	240	.009	H	000	.002
		S—rail end	S-241	222	.015		.014	.007
159	823,100	S. base—rail end	311	263	.007	H	.002	.008
160	611,700	Both top N. 2⅛ in. from rail end	N-279	200	.011	H	000	000
		S. 1⅞ in. from rail end	S-277	234	.020		000	000
161	331,300	S. base—rail end	271	222	.014	H	.006	.009
162	500,000	N. base—to bolt hole	292	210	.004	H	.002	.007
163	339,600	S. base—rail end	269	234	.006	H	.009	.004
164	697,300	S. base—rail end	269	222	.006	H	.006	.005
165	445,500	N. base—rail end	271	228	.005	H	.013	.001
166	500,900	Both base—N. to bolt hole	N-286	248	slight	H	.003	000
		S. 1 in. from rail end	S-302	240	slight		000	000
167	1,090,400	S. top rail end	282	234	.004	H	000	.001
	509,200	Average						

*Equivalent BHN is average of 5 Rockwell B readings converted to Brinell.

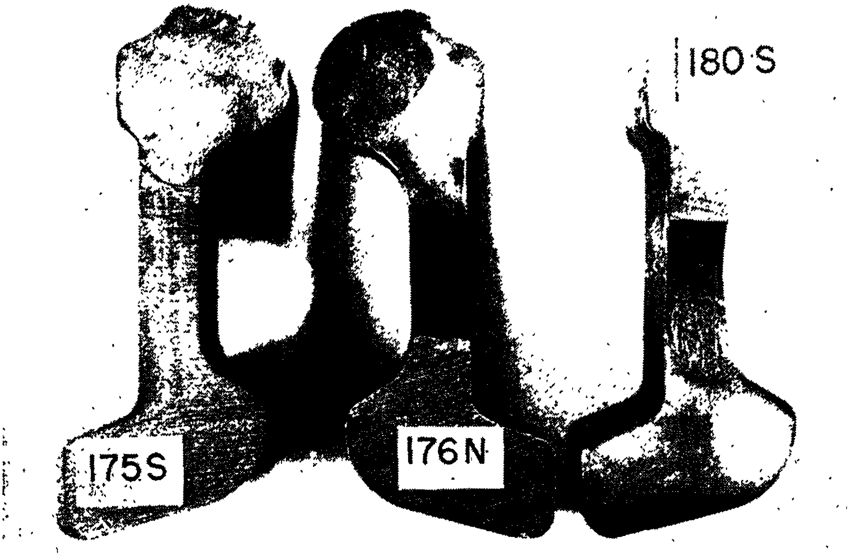


Fig. 2.—Fractures of 115 RE Headfree Bars.
Crack on Bar 175 S started in gouge caused by rail end.
Cracks on Bars 176 N and 180 S progressed to oval bolt holes.

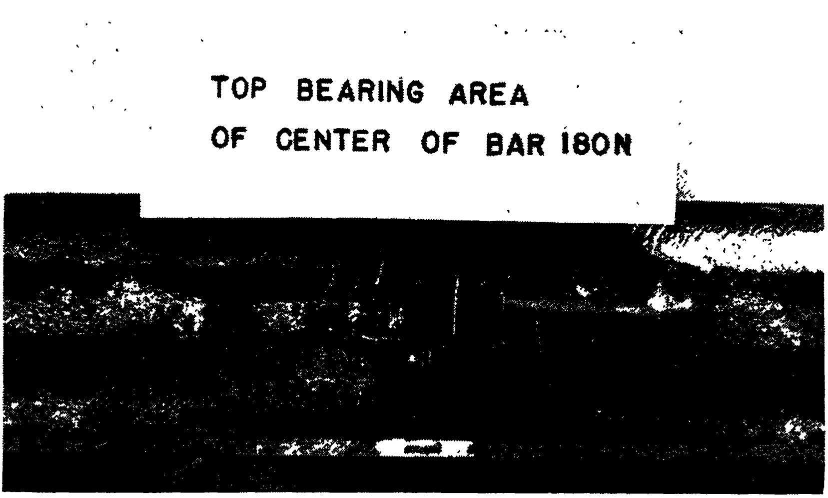


Fig. 3.—Small Cracks Outlined by Magnaflux on Top Surface of 115 RE Headfree Bar after 1,462,000 Cycles.

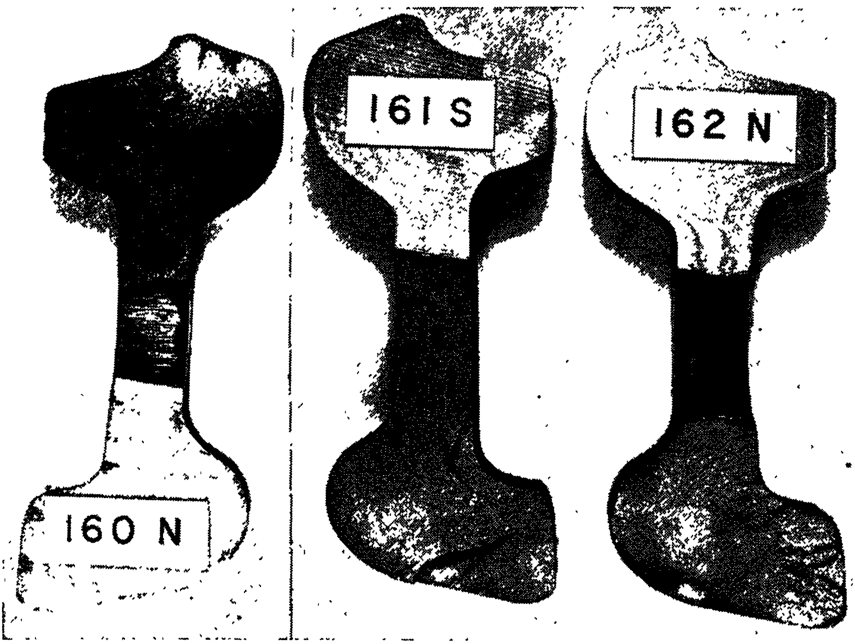


Fig. 1.—Fractures of 133 RE Head Contact Bars.
Cracks on bars 160 N and 162 N progressed to oval bolt holes.

Metallographic Studies

Sections were sawed from all failed bars at the fatigue fracture and micrographs at 100X magnification were made to determine the extent of decarburization of the bar surface and to observe the grain structure. Depths of decarburization are tabulated in Table 3 and range from slight (less than 0.001 in.) to 0.024 in. No clearly defined correlation between cycles for failure and depth of decarburization is apparent.

Failed Joint Bars from Service

It was thought that laboratory examination and tests on a large number (400 to 500) of failed bars from service might provide useful information and statistics regarding joint bar failures. One hundred broken bars have been received from the New York, Chicago & St. Louis Railroad through the courtesy of W. E. Cornell, engineer of track. All of the bars were 131 K14 headfree 36-in. bars and had failed from the top surface at or near a rail end. Brinell hardness readings, taken on the top fishing surface near the fracture, after grinding off 1/32 in., ranged from 164 to 277, with 86 of the 100 bars falling in the range 200 to 260 Brinell.

Twelve bars approximately 10 Brinell numbers apart were selected for metallographic examination and tensile tests. Brinell tests on the cross sections of these 12 bars indicated that the hardness at the center of the head of the bars was lower than the hardness near the surfaces by 15 to 69 Brinell numbers. Micrographs revealed pearlitic grain structure on the bars with Brinell hardness on the cross section from 149 to 182 and

TABLE 4.—BRINELLS AND PHYSICAL PROPERTIES OF FAILED BARS FROM SERVICE

Lab. No.	*Hardness Near Top surface BHN*	*Hardness on Cross-Section BHN.*	*Tensile Strength Psi*	*Yield Strength Psi.*	*Red. of Area Percent*	*Elong. 2 in G L Percent*
A28	164	149	80, 900	40, 600	49.0	26.4
A69	173	155	83, 000	42, 200	49.0	26.0
A88	183	166	86, 900	41, 700	40.7	24.0
A52	191	166	89, 300	47, 700	48.8	26.0
A32	205	157	86, 900	46, 400	48.5	25.5
A30	216	156	83, 000	42, 300	47.9	25.5
A65	228	182	95, 900	55, 900	53.6	23.5
A66	234	200	99, 000	62, 600	54.5	23.5
A82	244	185	94, 500	64, 500	58.0	24.5
A91	254	185	95, 600	61, 400	58.7	24.5
A23	263	215	109, 000	69, 000	50.0	20.0
A1	277	234	117, 000	72, 100	45.2	18.5

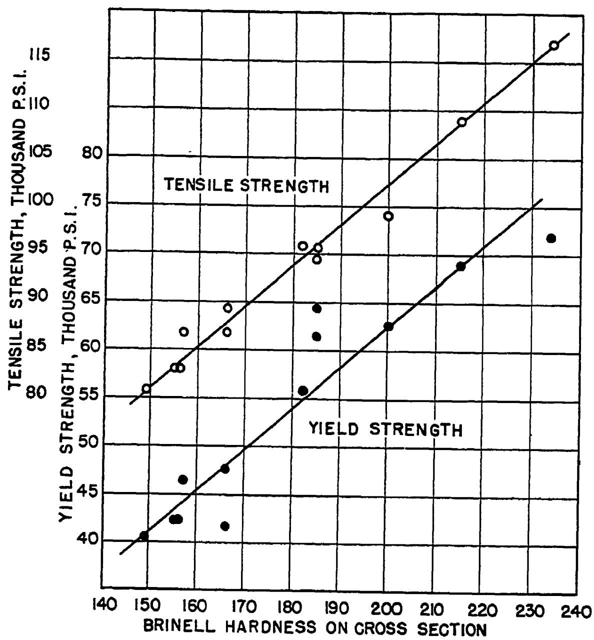


Fig. 5.—Physical Properties vs. Brinell of Joint Bars from Service.

3. Micrographs, taken on all failed bars, revealed decarburized bar surfaces to varying depths up to 0.024 in. No clearly defined correlation between cycles for failure and depth of decarburization was apparent.

4. Brinell and tensile tests on 12 of 100 failed bars from service indicated higher hardness readings near the surface of the bars than at the center of the head. Ten of the 12 bars tested failed to meet the specifications of 100,000 psi. minimum tensile strength and 11 fell short of the 70,000 psi. minimum yield point.

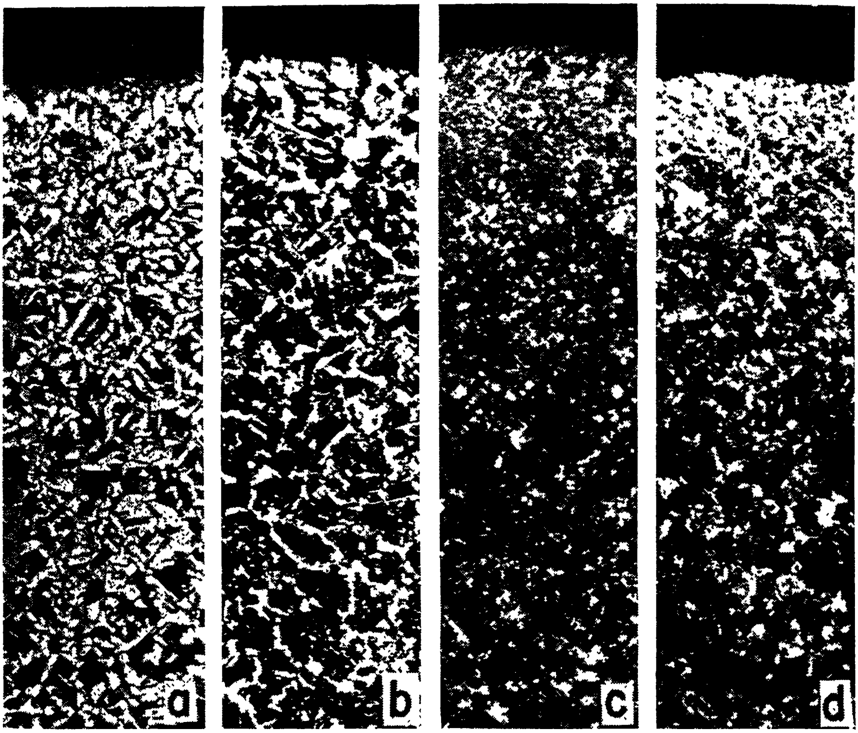


Fig. 4.—Micrographs From Joint Bars Which Failed in Service. Magnification 100×.
(a) Bar No. A28, Brinell (cross section) 149, pearlitic grain structure.
(b) Bar No. A65, Brinell (cross section) 182, pearlitic grain structure.
(c) Bar No. A66, Brinell (cross section) 200, sorbitic grain structure.
(d) Bar No. A1, Brinell (cross section) 234, sorbitic grain structure.

sorbitic grain structure on bars with Brinells from 200 to 234. Fig. 4 shows micrographs from four of the bars.

The physical properties of the 12 bars as determined by the laboratory tensile tests are listed in Table 4.

Since specifications call for a minimum tensile strength of 100,000 psi. and minimum yield point of 70,000 psi., only two of the twelve bars tested passed the specifications as to tensile strength and only one bar passed specifications as to yield point.

Brinell vs. tensile strength and Brinell vs. yield strength are plotted in Fig. 5 for these 12 specimens. The Brinell readings plotted were those taken on the cross section at the center of the head of the bars.

Summary

1. Twelve tests of 133 RE head contact 36-in. bars averaged 509,200 cycles. Of 16 failed bars, 10 started from the base, 5 from the top, and one from both top and base.

2. Twelve tests of 115 RE head free 36-in. bars averaged 1,462,450 cycles. Five of the joints ran to 2,000,000 cycles with no failure.

Up to the present time no explanation can be offered for the difference in fatigue life due to the location of the built-up metal on the engine burn. Tests on welded engine burns have not progressed far enough to lead to any conclusions.

Report on Assignment 10

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention

L. S. Crane (chairman, subcommittee), C. H. Blackman, T. A. Blair, B. Bristow, C. B. Bronson, E. E. Chapman, C. J. Code, P. O. Ferris, J. L. Gressitt, G. F. Hand, C. B. Harveson, L. R. Lamport, C. C. Lathey, E. E. Mayo, Ray McBrian, E. H. McGovern, R. J. Middleton, L. T. Nuckols, Embert Osland, W. C. Perkins, G. A. Phillips, J. G. Roney, I. H. Schram, A. A. Shillander, G. L. Smith, Barton Wheelwright, R. P. Winton, J. E. Yewell.

This is a progress report presented as information.

As explained in previous reports, the investigation is divided into four groups of subjects, the first being handled directly by the subcommittee, the second by the research staff of the Engineering Division AAR, the third by the University of Illinois and the fourth by the Battelle Memorial Institute. Funds are provided by the AAR for the work being done by Group 2 and jointly by the AAR and the AISI for work being done by Groups 3 and 4.

Up to this time the research investigation has failed to disclose a solution to the problem. Metallurgical investigations conducted by Battelle Memorial Institute have been most helpful in classifying the various types of defects covered by the assignment of the subcommittee and have provided a specific terminology for each type of defect covered by the general classification of shelly spots.

Continued field tests have been made on those materials which the research work has indicated to be promising. The following comments are offered relative to the progress made so far in order of the groups given above:

Group 1

Item (a).—A study of the data submitted indicates no definite relationship between the chemistry and shelling except insofar as the hardness of the running surface of the rail is affected.

Item (b).—A study of data submitted as to curvature, elevation, speeds and grades, reveals no definite trend, but consideration is being given to the compilation of a greater volume of statistics for the purpose of an expanded statistical approach along this line.

Item (c).—Tests conducted on the Delaware & Hudson on two similar curves, one equipped with lubricators and the other without, have revealed that lubrication does not affect the development of flaking spots and gage corner shelling.

Item (d).—Experience on the Chicago, Milwaukee, St. Paul & Pacific and the Atchison, Topeka & Santa Fe indicates that transposing high rails, which have developed gage corner shelling, to the low rail, if done in time, is well worthwhile.

Item (e).—Tests on the Milwaukee, the Norfolk & Western, and the Pennsylvania have shown that rail slow-cold-worked under traffic in nonshelling locations and relaid in shelling locations possesses little if any greater resistance to gage corner shelling than ordinary rail.

Report on Assignment 9

Rail Fractures Resulting from Engine Wheel Burns, Including Effect of

Repairing Such Burns by Oxyacetylene or Electric Welding

J. B. Akers (chairman, subcommittee), J. E. Armstrong, H. B. Barry, C. H. Blackman, C. M. Chumley, H. R. Clarke, C. J. Code, L. S. Crane, C. B. Harveson, S. R. Hursh, H. S. Loeffler, R. F. Logan, Ray McBrian, L. T. Nuckols, E. E. Oviatt, W. C. Perkins, G. A. Phillips, J. G. Roney, E. F. Salisbury, F. S. Schwinn, A. A. Shillander, G. L. Smith, A. P. Talbot, R. P. Winton, J. E. Yewell.

This is a brief progress report presented as information.

An examination of the rolling load test data presented in the last previous report on this assignment, Proceedings, Vol. 49, 1948, page 429, indicated that considerable variation was still being obtained in rolling load tests of welded and unwelded engine burns.

It was felt that some of this variation was possibly caused by lack of control in preparing the engine burn specimens.

At the suggestion of Professor R. E. Cramer it was decided to prepare some artificial engine burns utilizing the facilities of the wheel testing machine at the University of Illinois. Twenty-one specimens were artificially burned in this machine with the wheel rotating at a speed of 15 mph., the rails being applied to the moving surface of the wheel for 3-sec. intervals. The burns produced by this method were approximately 1½ in. wide by 2½ in. long and appeared to be quite uniform in nature.

Below is a tabulation of the rolling-load tests completed on these specimens up to the present time:

Tabulation of Rolling-Load Test Results

Rails artificially engine burned on brake shoe testing machine.
Large size burns approximately 1½ in. by 2½ in.
Wheel load 50,000 lb.; cantilever support. Engine burn located between support and wheel path.
Approximate bending moment 750,000 in.-lb.

Test No.	*Unwelded Burns Cycles to Failure*	*Type of Failure*
Build-up of engine burn metal toward wheel path:		
105	483,000	Progressive through engine burn
106	407,000	"
107	567,800	"
108	922,800	"
110	279,300	"
111	218,200	"
112	389,300	"
115	482,500	"
Build-up of engine burn metal away from wheel path:		
109	1,240,000	Progressive through engine burn
113	2,690,000	No failure
Welded engine burns—hand welded:		
118	2,100,000	No failure

At the present time the laboratory has on hand an additional four specimens which were repaired by hand welding and five specimens which were repaired by utilizing the semi-automatic welding machine developed by the Oxweld Railroad Service Company.

Research work is being actively pursued toward the development of an economical alloy steel rail analysis capable of being manufactured with standard open-hearth equipment by the Carnegie-Illinois Steel Corporation and it is hoped that some test rails may be laid within the coming year.

Group 2

The Engineering Division research staff has continued to assist the committee in the direction of the research work and the field studies.

Group 3

The third portion of the assignment is covered by a report prepared by Professor R. E. Cramer, which follows as Appendix 11-a.

Group 4

The fourth portion of the assignment is covered by a report prepared by Messrs. J. E. Campbell, H. O. McIntire and G. E. Manning which follows as Appendix 11-b.

Appendix 10-a

Eighth Progress Report of the Shelly Rail Studies at the University of Illinois

By R. E. Cramer

Special Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

The shelly rail studies at the University of Illinois are financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Acknowledgment is given of the help of Frank Bolda, T. S. Noggle and Daniel Kennedy, student assistants, and Marion Moore, mechanician. Special acknowledgment is made of the assistance of the metallurgists of the rail manufacturers and the engineers of the railroads who supplied the rails used in the laboratory tests.

Examination of Shelly Rails from Service

Two rails were selected from the high side of a 4-deg. curve of the Central of Georgia Railway for laboratory studios. These rails had carried 63,385,600 tons of traffic at average speeds of 35 mph. in both directions. The superelevation of the curve is 4½ in. and there is a flange lubricator 2.4 miles from the curve.

One rail, No. 601, showed flaking along the gage corner over its entire length and had also developed 6 or 7 small black shelly spots. Fig. 1a shows the gage corner of this rail as received from service and reveals two black spots and flaking on the gage corner.

The second rail, No. 602, contained 30 black shelly spots, 3 of which were from 8 to 12 in. in length. About half of these shelly spots had heavy lips extending down along the gage side of the rail. Fig. 1b shows three of the shelly spots and the lips on the side of the rail head.

Both rails were examined for internal shelling which had not reached the sides of the rail head or formed black spots. Magnetic, thermo-magnetic and ultrasonic testing procedures were tried but no nondestructive method was found which would locate internal horizontal shelling cracks. The final procedure adopted was to saw the rail head

Item (f).—Tests on the Norfolk & Western of special high carbon rail with carbon ranging from 0.84 to 0.91 percent have indicated that high carbon rail will retard the onset of gage corner shelling but will not eliminate it; moreover, the high carbon rail has a tendency to heat check and this in turn causes gage corner flaking. It was noticed that the sharpest curves did not flake or develop gage corner shelling nearly as much as the lighter curves.

A review of experience on several railroads has indicated that the new AREA rail sections, incorporating the redesigned gage corner fillet, retard the initial development of gage corner shelling but do not prevent it.

Tests conducted on the Pennsylvania to compare the resistance of control cooled rail versus hot bed cooled rail to gage corner shelling have indicated that both types of rail shell equally under similar conditions and gage corner shelling is not chargeable to control cooling. Extensive laboratory tests conducted on control and noncontrol cooled rail by Battelle Memorial Institute and summarized in this report, confirm this finding by indicating there is no difference in the physical properties of the rail steel.

Tests conducted on the Duluth, Missabe & Iron Range of heat-treated rails have indicated that heat-treated rail steel will materially extend the life of a rail before gage corner shelling.

Additional tests of heat-treated rail steel have been installed as follows:

Twelve rails of 155 PS section, heat treated by the Bethlehem Steel Company, Steelton plant, were laid on the high side of Curve No. 11, east of Tyrone, Pa., Middle Division of the Pennsylvania Railroad January 24, 1949.

At the same time 12 non-heat-treated end-hardened rails from the same heats were laid on this curve.

The rails were laid alternately, two non-heat-treated, end-hardened, and two heat-treated rails. Curve No. 11 is a 6-deg. curve with 6-in. superelevation, located in 3-track territory, the track in which the test rails were laid carrying a large percentage of eastbound freight and passenger traffic. The average tonnage over this territory will approximate 60,000,000 tons per annum. Up to the present time the heat-treated rails have failed to show any unsatisfactory surface condition except for one flake spot on one heat-treated rail and the non-heat-treated rails are beginning to exhibit light gage corner flaking.

On May 2, 1949, the Chesapeake & Ohio laid 12 132 RE heat-treated rails and 12 132 RE non-heat-treated rails on the Logan subdivision, Barbersville District, at M. P. 7, in the vicinity of Martha, W. Va. Six heat-treated and six non-heat-treated rails were laid on the high side and on the low side of the curve with the non-heat-treated rails located from the center to the beginning of the curve and the heat-treated rails located from the center to the end of the curve. The curve is a 3-deg., 6-min. curve, with 2½-in. superelevation. This curve is located on the heavy coal traffic line of the C. & O. but up to the present time has not accumulated enough tonnage to develop any information.

On May 3, 1949, the Norfolk & Western laid both heat-treated and non-heat-treated end-hardened 132-RE rail on a curve in its westbound track at M. P. NA 6, near Kermit, W. Va. The heat-treated rails were laid in the center of the curve, 12 on the high side and 11 on the low side, while 12 of the non-heat-treated end-hardened rail were laid at each end of the installation of heat-treated rail, that is, 6 on the high side and 6 on the low side. This curve is a 6-deg. curve with 5 in. of superelevation. Up to the present time insufficient tonnage has passed over this track and no conclusions can be observed.

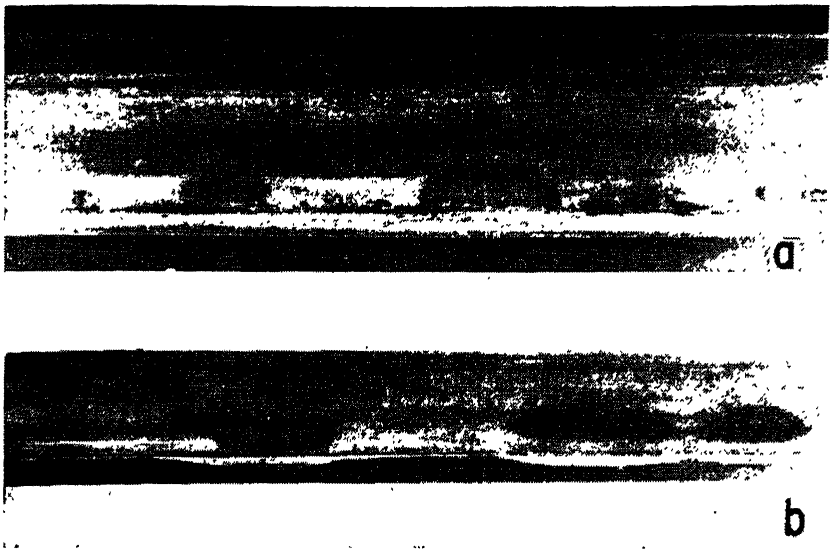


Fig. 1.—Shelly Spots on Two Rails From Service.

(a) Rail 601. Note two black spots and flaking along gage corner.

(b) Rail 602. Note three black spots and lips on side of rail head.

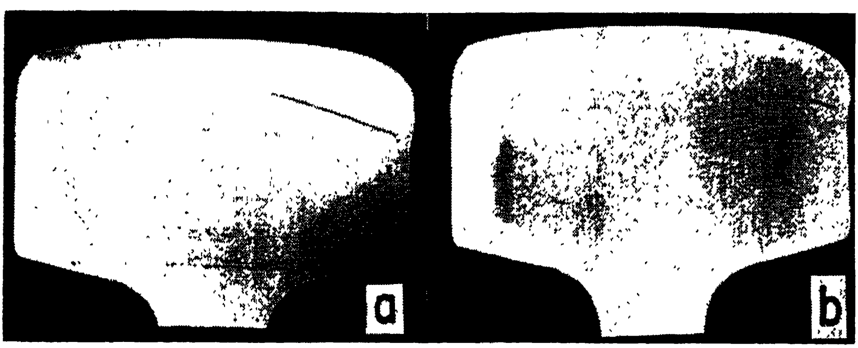


Fig. 2.—Cross-Sections of Rail 602 Showing Internal Shelling Cracks. Cracks Outlined by Magnetic Particles.

(a) Largest internal shelling crack found.

(b) Smallest internal shelling crack found.

from the web and then saw the head into 1 to 1½-in. lengths. These cross sections of the rail head were polished and examined for internal cracks by the wet magnetic particle method. No cracks were found in Rail 601 which did not extend to the outside surface but this rail had shallow cracks along the gage corner for almost its complete length. The black spots appeared to be areas where the gage corner cracks had extended across the rail head from ¾ to 1¼ in. These shelly spots were comparatively shallow and are believed to have been of surface origin.

Five internal cracks were found in Rail 602. Fig. 2a shows the largest of the internal cracks and Fig. 2b the smallest internal crack as located by the magnetic particle method. Fig. 3 shows four of the internal shelling cracks opened up. The interior of these cracks was silvery bright except for slight corrosion which took place when the specimens were cooled in water, during grinding, in preparation for the magnetic particle testing. Fig. 3b shows a longitudinal streak, and similar interior lines were found in some of the small black spots which were opened up. However, the larger black spots were so worn by friction and corrosion that no longitudinal lines or growth rings could be observed. Fig. 4 shows the smallest shelling crack (also shown in Fig. 2b) at 6× magnification. It will be noted that there is a short vertical component in the horizontal crack. When such cracks are opened up, this vertical ridge appears as a longitudinal streak on the fractured surface.

From the observation of these two rails it appears that there are two processes by which black shelly spots develop, those starting on the gage corner and working across the rail at a comparatively shallow depth and the deeper shelling which starts internally and spreads both toward the center of the rail head and toward the gage side of the rail head. Observance of many opened up shelly spots indicates that the latter type usually starts rather close to the side of the rail head and spreads faster toward the center of the rail head than toward the gage side. The explanation for this could be that more wheel loads make contact with the rail treads nearer the center line of the rail than close to the gage side. Fig. 5 shows a cross section of a rail from service at 6× magnification with shelling cracks starting both at the surface and in the interior of the rail. This is a rather unusual condition but has been found in a few rails previously examined.

Fig. 6a shows a small detail fracture from service which developed from head checks as shown in Fig. 6b. This type of straight cracks on the gage corner forms when the surface metal has been hardened by wheel slippage, usually on the low rail of a curve. The white layer shown in Fig. 6c was on the gage corner of this rail. It is a layer of martensite only 0.002 in. in thickness. It is hard and brittle which accounts for the numerous long straight head checks. These cracks cannot be seen easily until the steel is etched in acid to increase their width.

Laboratory Tests to Produce Shelling

During the past year, 23 specimens have been tested in the cradle type rolling-load machine. Table 1 lists the chemical analysis, physical properties and results of rolling-load tests of these specimens.

Rail 1100 was an as-rolled alloy rail containing about 0.5 percent each of chromium and silicon and 0.06 percent vanadium. It developed a Brinell hardness between 320 and 330 as cooled in air. Two rolling-load tests gave high values and one test failed at 1,618,000 cycles. This latter specimen was investigated and Fig. 7a shows a prominent streak along the center of the shelling crack developed in the rolling-load machine. A microscopic examination was made on a cross section of this streak near the crack, which revealed the nonmetallic inclusions shown in Fig. 7b. These inclusions can account for the low test obtained on this one specimen. The other two tests of this low alloy

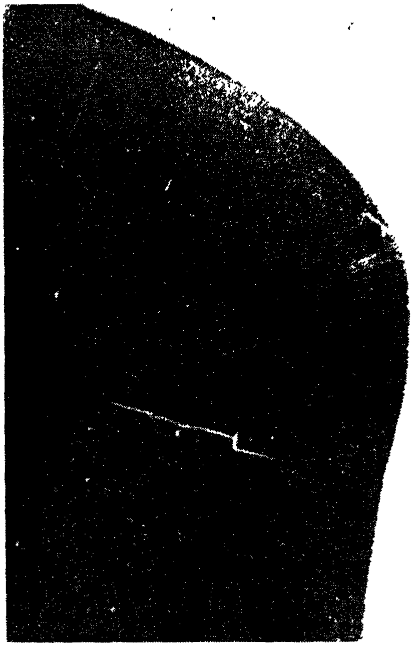


Fig. 4.—Smallest Shelling Crack at 6$\times$ Magnification.

Crack is outlined with Magniflux powder. Darkfield illumination shows polishing scratches as thin white lines.

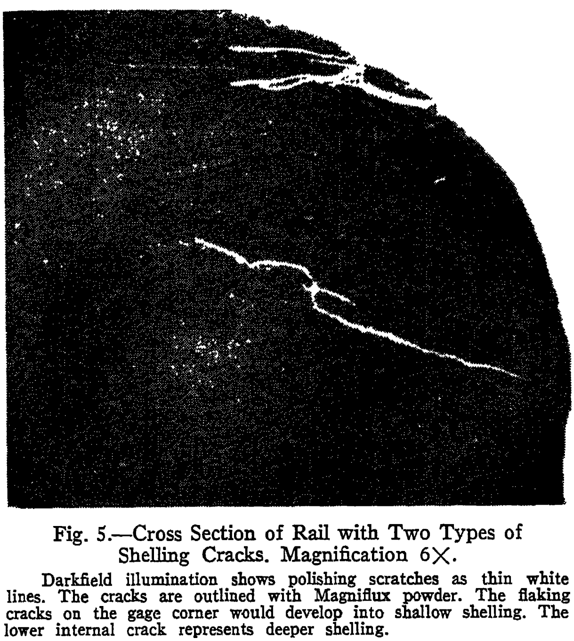


Fig. 5.—Cross Section of Rail with Two Types of Shelling Cracks. Magnification 6$\times$.

Darkfield illumination shows polishing scratches as thin white lines. The cracks are outlined with Magniflux powder. The flaking cracks on the gage corner would develop into shallow shelling. The lower internal crack represents deeper shelling.

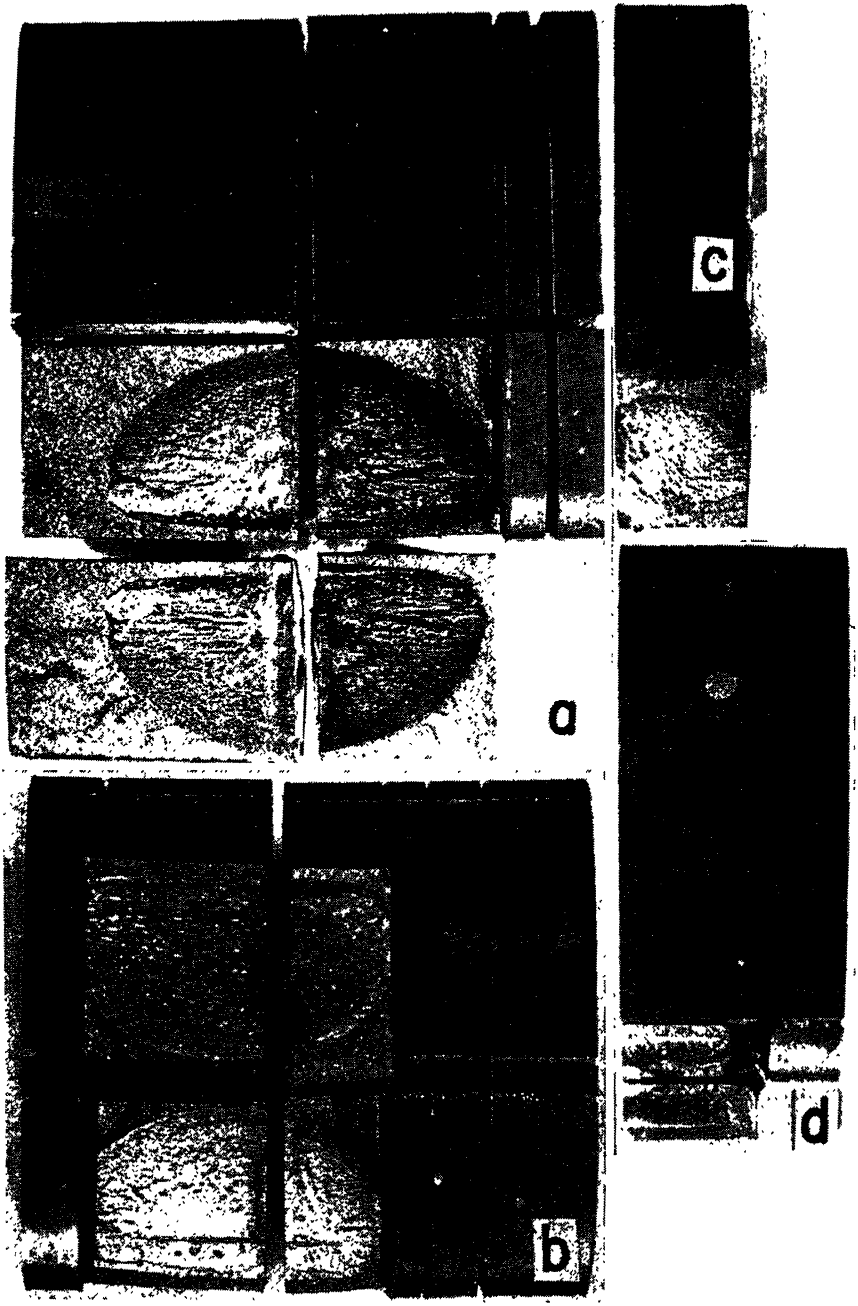


Fig. 3.—Four Internal Shelling Cracks in Rail 602.

Fig. 7.—Shelling Crack and Micro of Rail 1100A.

(a) Opened up shelling crack showing streak which may have caused early failure. Natural size.

(b) Photomicrograph of unetched cross section of streak. 100× magnification. These nonmetallic inclusions can account for the early failure of this specimen.

Fig. 8 shows cross sections of four of the shelling cracks produced in the laboratory rolling-load machines. Fig. 11 shows three of the shelling cracks opened up. These cracks start inside the rail head usually ¼ to ¾ in. from the side of the rail head. This has been proved many times by stopping the rolling-load machine when the first very short cracks appear on the side of the rail head. When these rails are sectioned they show that these surface cracks are not the main shelling crack but are actually surface cracks in the bulged metal above the shelling crack. This is shown clearly in parts a, b and c of Fig. 8. When the main cracks are opened up they are found to be two to five inches in length and over one inch in width. The surfaces of these cracks are bright and highly polished indicating that no air had entered the cracks.

It will be noted from Table 1 that no shelling cracks developed in specimens, Nos. 1100 B and 1114 A, both of which were removed from the rolling machines at 6 million

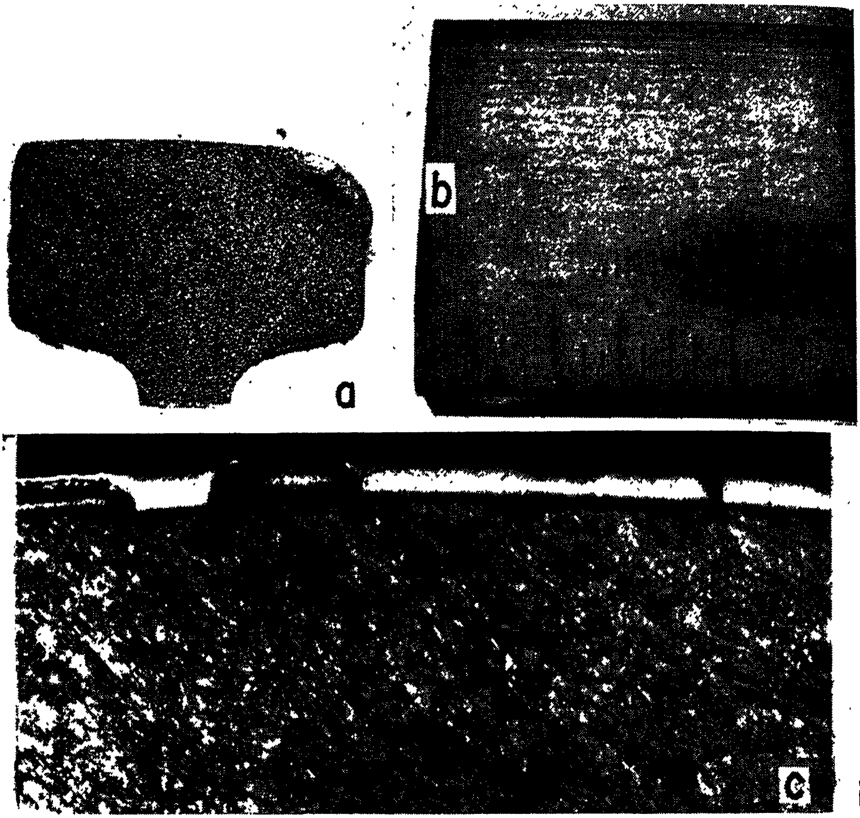


Fig. 6.—Detail Fracture from Head Checks on Low Rail on Curve.

(a) Small detail fracture at gage corner.

(b) Gage corner after etching in acid to reveal head checks in area hardened by wheel slippage. Etched in hot 50-percent hydrochloric acid.

(c) Photomicrograph showing martensite on gage corner where straight head checks developed. Magnification 100X. Etched in 2-percent nital.

rail gave as good rolling-load tests as the 3 percent chromium rails reported in previous years. It gives considerable promise that a commercially practical alloy rail may be developed to resist shelling.

The other rolling-load tests were on heat-treated rails of standard chemical analysis and their companion rails from the same heats which were not heat treated. Two groups of these rails, Nos. 1109 to 1116, covered tests of different drawing temperatures for the quenched specimens. and Nos. 1118 and 1120, Bethlehem 155-lb. rails, are specimens representing heat treated rails laid in the tracks of the Pennsylvania Railroad. Most of the heat treated specimens ran 3 or 4 million cycles in the rolling-load machines, as compared to about one million cycles for companion standard carbon rails from the same heats. These results indicate that if a practical and economical method of heat treating rails were developed that they would resist shelling in service several times as long as standard carbon steel rails.

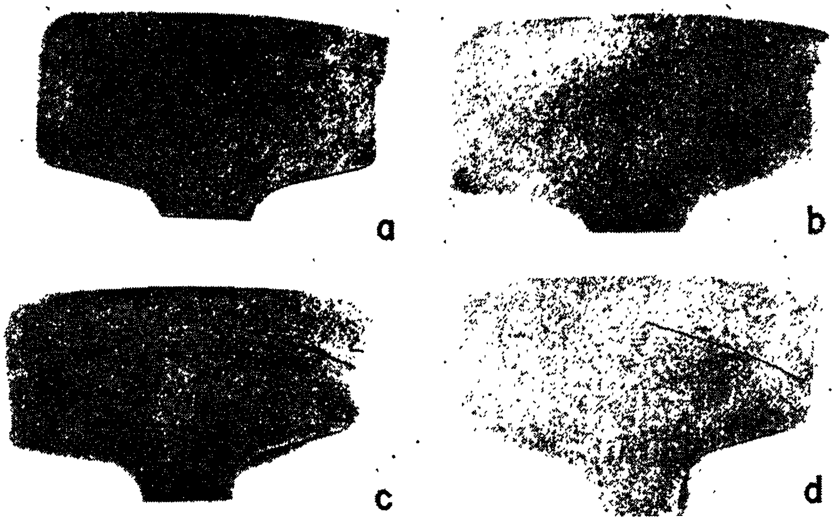


Fig. 8.—Four Internal Shelling Cracks Produced in Laboratory Rolling-Load Machines.

Specimens etched in 50-percent hot hydrochloric acid.

	Rail No.	Type of Rail	Average Brinell Hardness	Cycles for Failure
(a)	1100 C	Low alloy; as rolled	327	3,590,000
(b)	1112 A	Standard steel; oil quenched	326	3,386,900
(c)	1113 A	Standard steel; as rolled	282	1,672,000
(d)	1113 B	Standard steel; as rolled	280	1,074,000

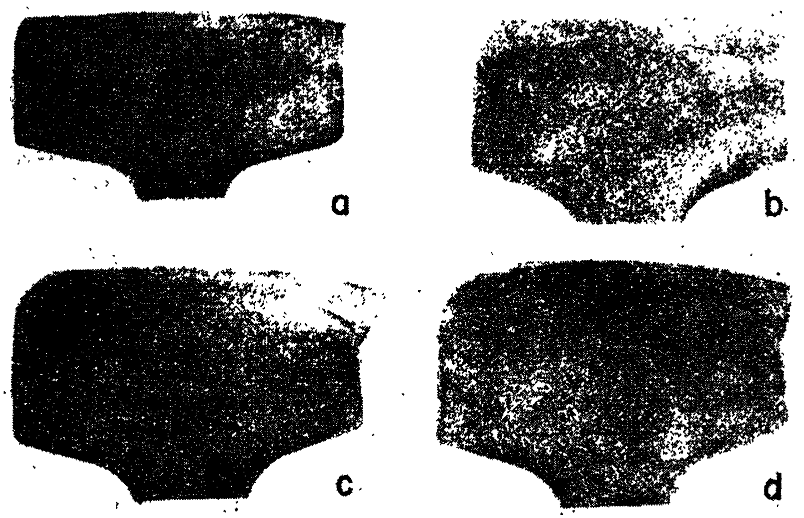


Fig. 9.—Laboratory Rolling-Load Specimens Etched in 50 percent Hot Hydrochloric Acid.

	Rail No.	Type of Rail	Average Brinell Hardness	Cycles in Rolling Machine
(a)	1100 B	Low alloy; as rolled	330	6,000,000
(b)	1118 A	Standard rail; oil quenched	347	4,764,000
(c)	1119 A	Standard rail; as rolled	264	782,000
(d)	1117 A	Standard rail; as rolled	272	350,000

A

Table 1.—Physical Tests and Cradle Rolling-Load Tests Since October 1, 1948

Specimen Number	Chemical Analysis C	Mn.	Si	Alloys	Heat Treatment Q = Quenched D = Drawing temp. deg. F.	Avg. Brin. Hard.	Yield Strength 0.2 o/o Psi.	Tensile Strength Psi.	Percent Elong. in 2 in. Percent	Red. of Area Percent	Charpy Value ft.-Lb. No Notch	Key Hole Notch	Endur. Limit Psi.	Cycles for Failure 50,000-lb. Wheel Load
1099 A	.80	.92			Water quench-soft	309	109,000	164,000	8	38	286		83,000	800,000
1099 B	"	"			" " "	320								1,373,000
1099 Web	"	"			" " "	316	108,000	170,000	7.5	31.4	234		84,000	
1100 A	.73	.98	.51	Cr. .59 Va. .06	Gary as rolled	319	93,900	157,700	7.	16.1	142		83,000	1,618,000
1100 B		"		"	" " "	330								6,005,000+
1100 C		"		"	" " "	327								3,590,000
1107 A	.09	.86	.36		Colo. as rolled	267	73,400	132,300	9	21	118		60,500	983,000
1107 B	"	"	"		" " "	271								1,086,700
1108 A	.80	.92	.16		Inland as rolled	271	69,900	133,300	7.3	13.9	106	1.9	61,500	1,157,700
1109 A	.70	.80	.18		Gary as rolled	268	65,500	129,000	8.2	17.3	122	1.9	60,500	1,215,000
1109 B	"	"	"		" " "	253								1,065,800
1110 A	"	"	"		Gary oil Q;D-725	344	106,000	165,600	9.0	30.4	242	9.1	82,500	3,120,100
1110 B	"	"	"		" " " "	340								1,941,900
1111 A	"	"	"		" " " 850	330	113,300	163,000	9.0	33.4	[illegible]	8.6	79,000	3,206,000
1111 B	"	"	"		" " " "	330								3,404,000
1112 A	"	"	"		" " " 990	326	100,400	160,300	9.5	36.8	263	9.1	83,000	3,386,900
1112 B	"	"	"		" " " "	319								1,867,700
1113 A	.80	.88	.16		Gary as rolled	282	68,500	132,500	8.3	15.3	88	3.5	61,000	1,672,000
1113 B	"	"	"		" " "	280								1,074,000
1114 A	"	"	"		Gary oil Q;D.-725	383	123,900	181,700	8.0	39.1	279	7.3	94,000	6,000,000+
1115 A	"	"	"		" " " -850	335	115,300	169,000	11.0	33.2	216	5.6	86,000	2,755,000
1116 A	"	"	"		" " " -990	340	104,700	171,700	12.0	32.4	249	8.6	84,000	3,711,000
1117 A	.76	.90	.16		Beth.155-lb.as rolled	272	80,700	137,300	11.0	16.1	111	3.6	59,000	350,000
1117 B	"	"	"		" " " " "	271								631,000
1118 A	"	"	"		" " oil Q;D.-740	347	114,000	171,800	12.3	35.3	311	8.4	78,000	4,764,000
1119 A	.75	.82	.17		" " as rolled	264	74,800	133,000	9.7	15.6	106	5.1	60,000	782,000
1120 A	"	"	"		" " oil Q.D.-740	352	127,900	177,600	10.7	30.5	260	9.6	81,000	5,000,000+

+ Specimen did not fail

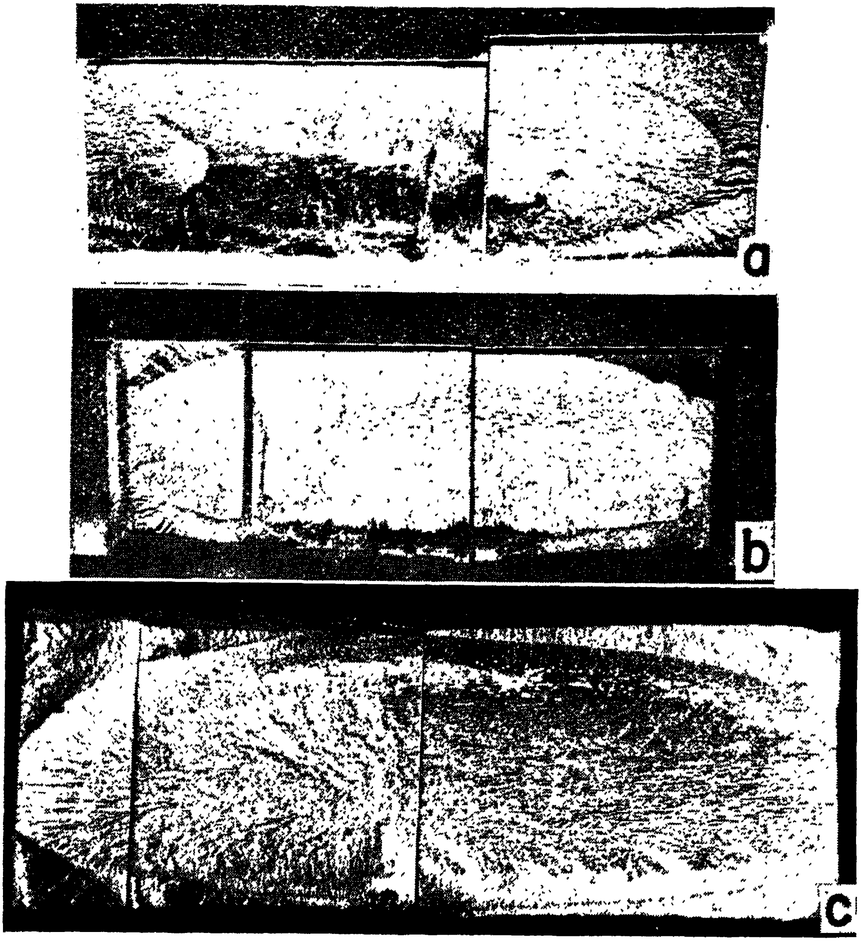


Fig. 11.—Three Internal Shelling Cracks Produced in Laboratory Rolling-Load Machines Opened Up.

Approximately natural size.

Rail No.	Type of Rail	Average Brinell Hardness	Cycles for Failure
(a) 1111 B	Standard steel; oil quenched	330	3,404,000
(b) 1112 B	Standard steel; oil quenched	319	1,867,000
(c) 1115 A	Standard steel; oil quenched	335	2,755,000

results of service tests of rails tested in the rolling-load machines last year give indications of this correlation but the service tests are not as yet completed.

Plans for Future Tests

Plans have been made to test several other alloy steel rails which are to be supplied by the rail mills. Also additional heat-treated rails representing experimental rails already in the tracks of the Norfolk & Western and the Chesapeake & Ohio have been received at the laboratory for rolling-load and physical tests.

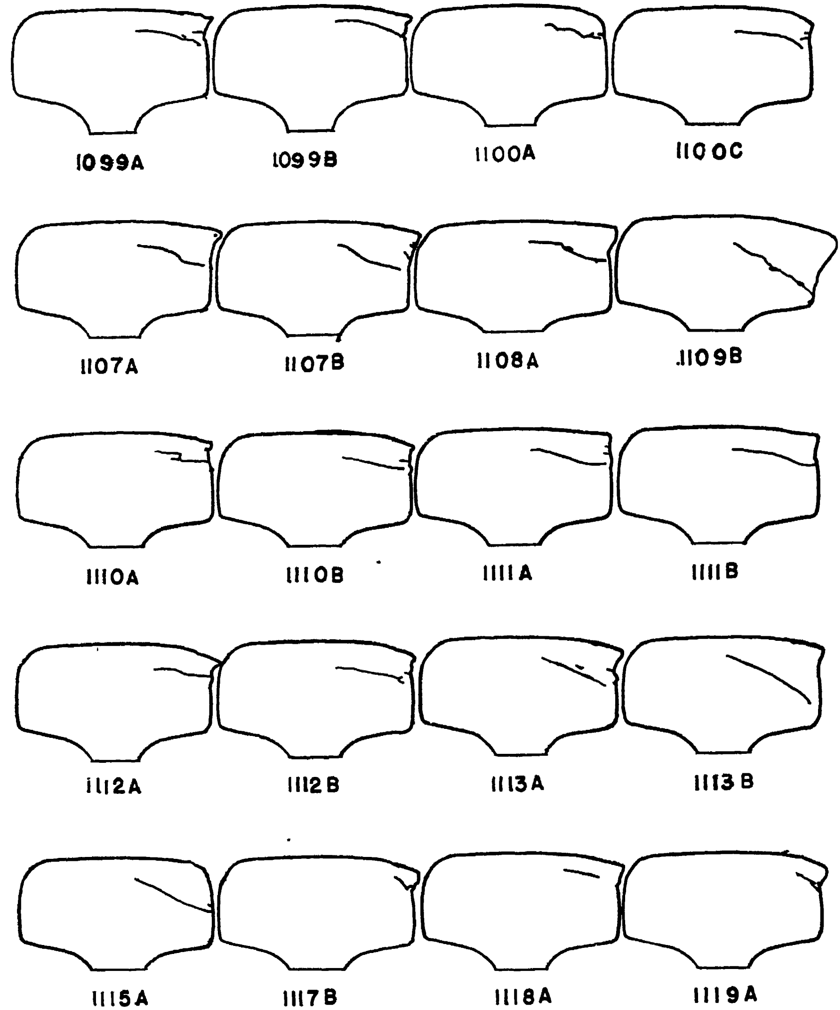


Fig. 10.—Location of Shelling Cracks Developed in Rolling-Load Machine.

cycles. Fig. 10 shows the location of the cracks in most of the laboratory specimens. Fig. 9 shows the details of four of the specimens which were somewhat different from the average. It will be noted that specimens 1117 A and 1119 A gave rather low rolling-load tests for standard carbon steel rails and both have cracks very close to the sides of the rail heads. Alloy rail No. 1100 B which did not crack is also included in this figure.

It is considered that the laboratory rolling-load tests produce shelling failures similar to the deeper type of shelling which develops in service. It is also believed that the laboratory tests give a quick method of determining the relative length of service which can be expected in track as compared with standard carbon steel rails. Preliminary

obtained which contained detail fractures. The rails had been located in track by detector cars and were either broken at the defect by the supplier, in which case short lengths from both sides of the fracture were submitted, or an unbroken section about three feet long, which contained the defective area, were submitted. Cooperating railroads in this project were:

Norfolk & Western Railway
Pennsylvania Railroad
Louisville & Nashville Railroad
Union Pacific Railroad
Southern Railway
Southern Pacific Company
New York Central Railroad
Northern Pacific Railway

Both the horizontal and vertical components of the defects were laid open so that the fractured surfaces could be examined. Forty-four of the rails having detail fractures were rolled since January 1, 1940, and were, therefore, control cooled by the standard practice. Chemical analyses and mechanical tests were made on them to determine their characteristic properties. The micro and macrostructures of these rails near the fractures were also examined.

In addition to the detail fracture rails, sections from 26 rails that were removed from track after engine burn failures were submitted. These 26 rails were rolled since January 1, 1940, and because they were removed from track for reasons which were not associated with the quality of the rail, they were considered to be representative of rail produced since January 1, 1940. They were tested in the same manner as the rails having detail fractures to determine whether there was any difference in the properties of the two groups.

In the remainder of the rails received, either no detail fractures could be found or they were rolled prior to 1940.

Fig. 1.—An Illustration of the Data Given with Each of the Specimens Investigated.

Louisville & Nashville R. R., T. C. & I. Heat 877160 (F-12-CC), April 1943, C 0.79 percent. Mn. 0.89 percent. Si 0.14 percent. P 0.029 percent. In service 5¼ years; 165 million tons carried in one direction at 60/45 mph. High rail having 3-deg. 10-min. curvature with 4-in. elevation. Brinell hardness 250. Microstructure-no ferrite. One large inclusion.

Appendix 10–b

Summary Report on the Examination of Rails Which Contain Detail Fractures

to

Joint Contact Committee on Rails of Association of American Railroads and American Iron and Steel Institute and Committee on Rail of American Railway Engineering Association

By J. E. Campbell, H. O. McIntire, and G. K. Manning

Battelle Memorial Institute

Abstract

The purpose of this phase of the project was (a) to examine detail fractures from shelling which had ben found in rail by detector cars and (b) to determine if the chemistry, mechanical properties or structures of detail fracture rails varied from those of random rails.

Examination of 54 detail fractures (46 from rail rolled since January 1, 1940) showed that such fractures may assume a wide range of size and shape. For convenience of discussion, they may be arbitrarily divided into four groups:

1. Those having a horizontal component less than ⅛ in. in length with the fracture progressing in a vertical (transverse) direction.
2. An "S" type having a short horizontal component with a short vertical component toward the surface at one end of the horizontal component and another vertical component toward the middle of the rail head on the other end of the horizontal component.
3. An "L" type fracture having a horizontal component in one direction from a vertical component.
4. A "T" type having a horizontal component which extends in both directions from the vertical component.

Of the fractures examined, 28 percent had bright, unoxidized surfaces, indicating no contact with the surface of the rail. About 70 percent of the rails containing detail fractures were taken from the high side of curves.

The average chemical analyses and mechanical properties of 44 rails having detail fractures and 26 random rails were so nearly the same that no distinction between the two groups was possible. The mechanical tests included hardness, tensile properties, and impact properties. Only rails rolled since January 1, 1940, were used in this comparison. Examination of deep etched structures and microstructures of detail fracture rails indicated that the steel used was of relatively good quality. Only an insignificant number of the rails contained any abnormal inclusions or one percent or more of ferrite at the grain boundaries near the area of the fracture.

Definitions

During the period from February 15 to September 15, 1949, a study of "detail fractures from shelling"* was made at Battelle. "Detail fractures from shelling"* are characterized by having components which lie in both the horizontal and vertical planes and are thereby distinguished from "gage corner shelling"* which have only a horizontal fracture. Through the cooperation of eight of the major railroads, 54 rail samples were

* As defined at the Joint Contact Committee meeting of AAR and AISI in Birmingham, Ala., October 1948.

Fig. 2.—Fracture in Rail SR10 from Southern Railway. It was of internal origin, and if there was a horizontal component, it was microscopic in size.

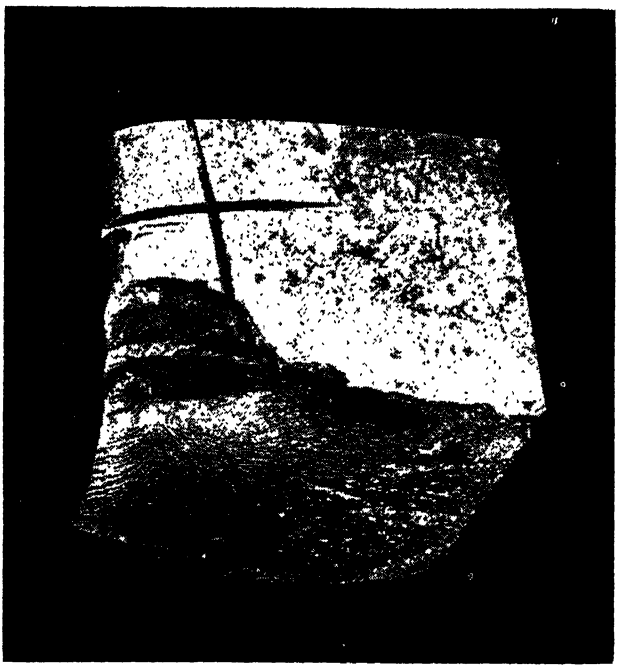


Fig. 3.—Fracture in Rail UP2-1 from Union Pacific Railroad, Showing Typical "S" Type Fracture.

Appearance of Detail Fractures

The detail fractures were cut from the rail samples received from the various roads and mounted on panels for observation. For ease of comparison, the 54 samples mounted in this way were divided into four groups. The first group consisted of two fractures having horizontal components less than ⅛ in. long. Only two specimens fell within this classification. One has bright surfaces as shown in Fig. 2, indicating that the fracture had not progressed to the surface of the rail at the time the rail was removed from service. The other fracture of this group is oxidized, indicating that it was opened to the atmosphere while in service. However, it also appeared to have been of internal origin.

The second group includes four fractures which are designated as "S" type fractures. These fractures have a short vertical component near the top surface of the rail which meets a horizontal component from 3/16 in. to ¼ in. below the surface. The other end of the horizontal component joins a second vertical component which progresses into the rail head.

A typical fracture of this type is shown in Fig. 3. Two of these fractures are bright and two are oxidized. The bright fractures and the oval markings on the surfaces indicate that the origins of these fractures are below the surface.

The third group consists of 34 fractures of "L" type. These fractures have one vertical component which is connected by a curved portion of the fracture to a horizontal component. The angle formed by the two components is usually greater than 90 deg. Two typical fractures of this type are shown in Figs. 4 and 5.

In 14 out of 16 cases, where the traffic was known to have moved over the rail in one direction, the horizontal component extended in the direction opposite to the direction of traffic. In the other two cases, the fractures had horizontal components in both directions from the vertical component. Ten of these fractures were bright and, therefore, had not broken through to the surface. Consequently, the origins of at least 30 percent of the "L" type fractures were below the surface of the rail. A longitudinal line can be seen along the middle of the horizontal component in Fig. 4. Similar lines appeared in the horizontal components of most of the bright fractures and many of the oxidized fractures.

Examination at high magnification of a section cut across one of these lines showed it to be a place where the fracture had progressed vertically for a short distance, producing a "step-like" appearance on the cross section.

The fourth group of detail fractures were called "T" type fractures. These fractures have horizontal components extending in both directions from the vertical components A typical example of a "T" type fracture is shown in Fig. 6. The vertical component makes a rather sharp angle with the horizontal component in one direction (usually the shorter of the two), while the other half of the fracture looks much like the "L" type. A wide variation exists between the relative dimensions of the various components. Some of the horizontal components are short in one direction and long in the other direction, and some have relatively short vertical components. Two of the "T" type fractures are bright and, therefore, did not extend to the surface of the rail.

Fig. 7a shows the relative numbers of the various types of fractures. The "L" type fractures are most common, while detail fractures having horizontal components less than ⅛ in. in length are least common. Of a group of 54 fractures, 15 or about 28

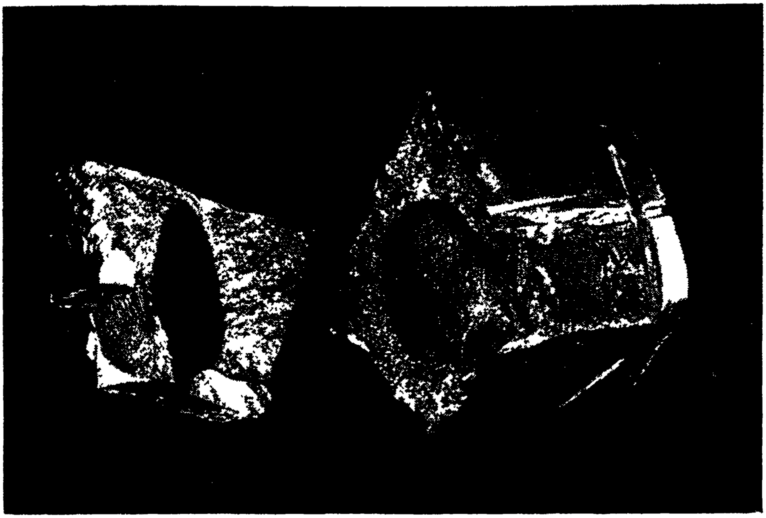


Fig. 7.—Fracture in Rail NY36 from the New York Central Showing a Typical "T" Type Fracture Having Horizontal Components in Both Directions from the Vertical Component.

percent were bright as shown in Fig.7b. Since many of the fractures, which started below the surface broke through to the surface before they were detected, the total number of fractures which started below the surface probably represents a large portion of the detail fractures examined.

Occurrence of Detail Fractures

Service data were submitted along with each rail sample. These data were examined for any correlation of service conditions with the occurrence of detail fractures. Admittedly the number of specimens studied was not sufficient to permit rigorous statistical treatment. However, the information is presented for whatever clues it may afford. The charts presented in Fig. 8 show that the detail fractures studied were found most frequently in rails which were on the high side of curves. In making the graphs in Fig. 8, only the 46 fractured rails which were rolled since January 1, 1940, were considered. Of these 46 fractures, 36 of them (78 percent) occurred on curves and 32 of them (70 percent) occurred on the high side of curves. This is good evidence that the service conditions which produce detail fractures are most severe on the high side of curves Furthermore, the average load carried by tangent rails which had detail fractures was 263 million tons as compared to an average of 242 million tons for detail fracture rails from the high side of curves having 3 deg. curvature or less. The average tonnage of fractured rails from the high sides of curves having more than 3 deg. curvature was 172 million tons. Information on tonnage carried by the rails was supplied for 8 tangent rails and for 12 rails from high sides of curves up to 3 deg. curvature and 12 rails for over 3 deg. curvature.

The locations in the ingots corresponding to the detail fracture rails were also noted. These data are presented in the labor chart of Fig. 8. Apparently, the rails having detail fractures were mostly "B", "C", "D", and "E" rails with only two "A" rails

Fig. 4.—Fracture in Rail SR7 from the Southern Railway Showing a Bright "L" Type Fracture from the Vertical Component End.

The longitudinal line can be seen in the horizontal component.

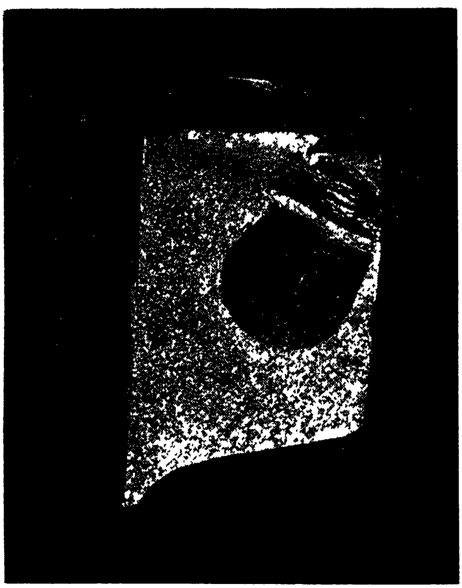
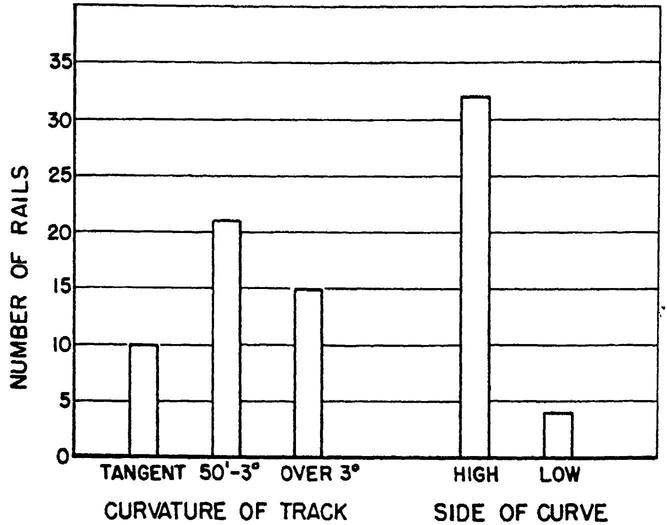


Fig. 5.—Fracture in Rail UP13 from the Union Pacific Railroad Showing an "L" type Fracture which Had Broken Through to the Surface.

Moisture penetrated into the fracture had caused corrosion which darkened the original fracture before it was removed from the track.



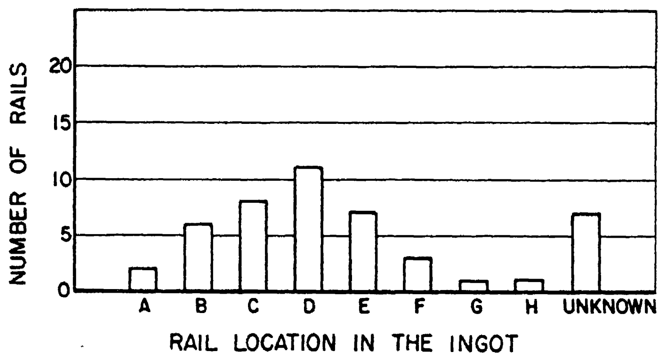


Fig. 8.—Occurrence of Detail Fractures with Respect to Track Curvature, Side Curve and Rail Number.

of the 39 for which these data were known. This is probably accounted for by the fact that very few "A" rails are laid on curves. Only a few mills produce "F", "G" and "H" rails and this may explain the low number of these rails found.

Inclusion Distribution and Grain-Boundary Ferrite

Sections of rails located near the fractures were deep etched to determine the relative cleanliness of the steel. The deep-etched structures near the fractures indicated that the steel in all of the rails examined, which were rolled since January 1, 1940, was relatively clean and was not characterized by severe segregation or abnormally large nonmetallic inclusions. The deep-etched sections can be seen in Figs. 1 and 6. The deep-etched patterns presented in the summary report of July 1, 1948, on shelly fractures are similar to those developed in the rails having detail fractures.

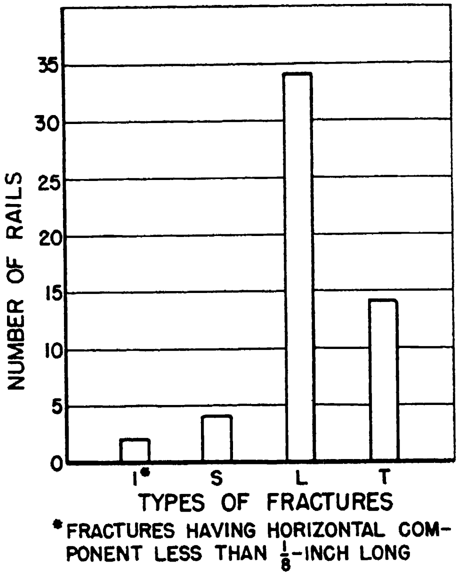


Fig. 7a.—Relative Number of Various Types of Fractures.

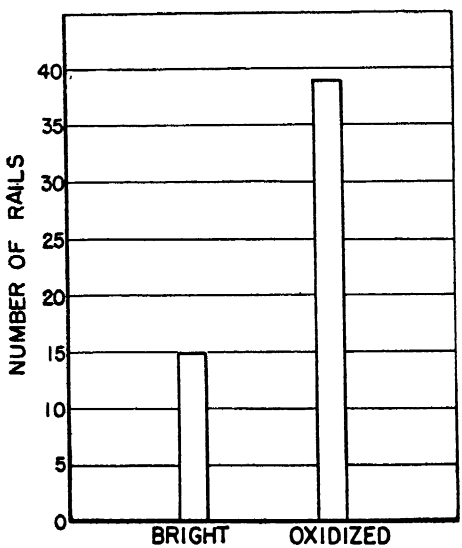


Fig. 7b.—Relative Number of Bright and Oxidized Fractures.

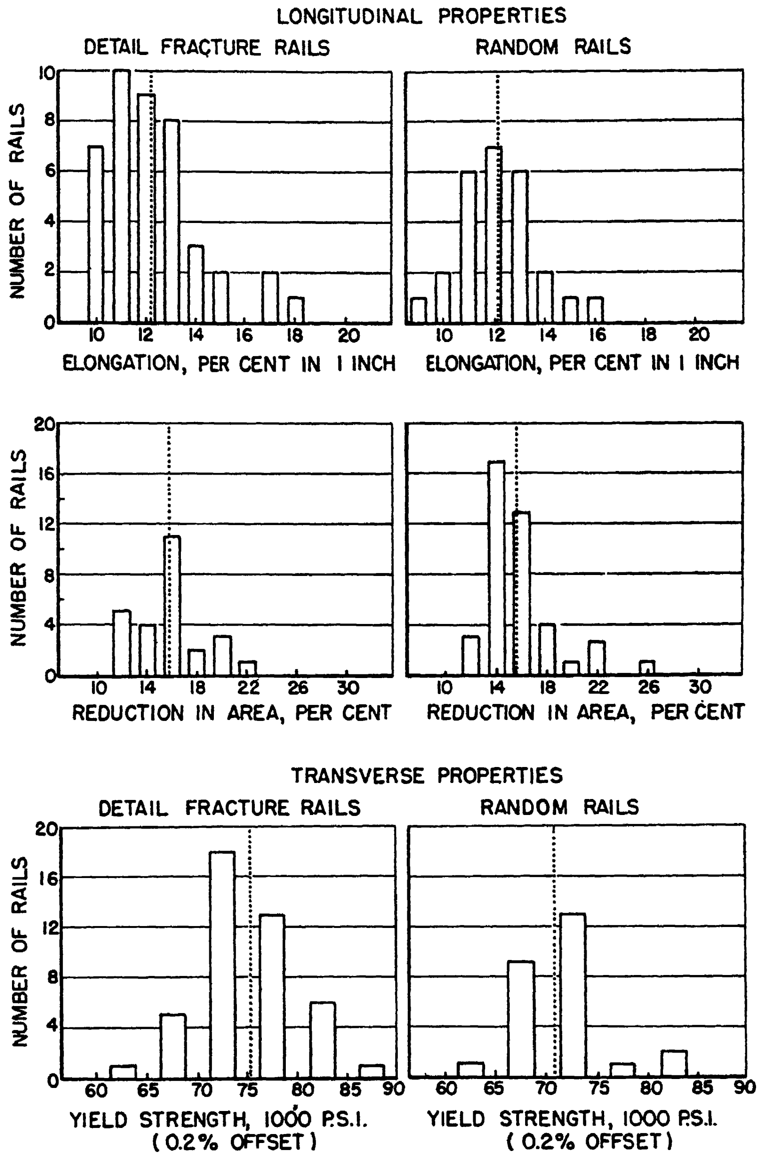


Fig. 10.—Distribution Graphs for Mechanical Properties; Broken Lines Indicate Average Values.

Samples for microscopic inspection were obtained between the fracture and the deep-etched sample for each rail. These specimens were mounted, polished, and examined under the microscope. The specimens were examined for inclusion distribution and size in the unetched condition and for grain-boundary ferrite after etching. The area of particular interest in these specimens was the area at about the same distance

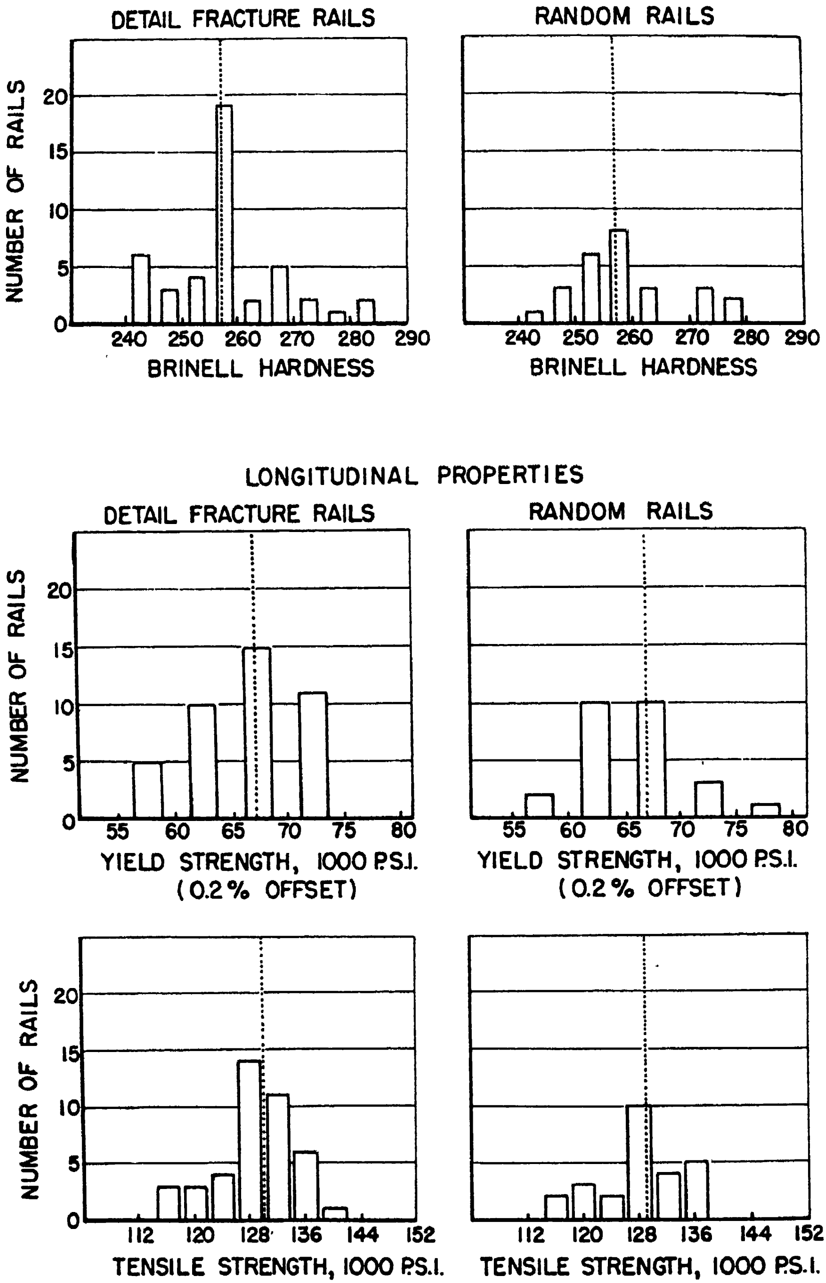


Fig. 9.—Distribution Graphs for Mechanical Properties. Broken Lines Indicate Average Values.

Chemical Analyses

Chemical analyses were made on all rails which were rolled since January 1, 1940. For the detail fracture rails, the chemical samples were obtained from the "0" position just below the gage corner and as close as possible to the fracture. Samples from the random rails were obtained in the corresponding position of the rail.

The results of the chemical analyses are given in Table 1. The average results and the ranges of the analyses for the detail fracture rails and random rails are nearly the same.

Mechanical Properties

Hardness and tensile tests were made on the head sections of detail fracture rails and random rails. Brinell hardness impressions were made on the back sides of sections later used for macro-etching. The impressions were made within the same area where the horizontal components of the fractures occur. The average hardness values and the maximum and minimum values are given in Table 2. The average Brinell hardness for fractured rails was 258 and for random rails was 257. The distribution of hardness values obtained on rails having detail fractures and on random rails are shown in the

TABLE 1.—CHEMICAL ANALYSES OF RANDOM RAILS AND DETAIL FRACTURE RAILS

		Chemical Analyses, Percent			
		C	*Mn*	*Si*	*P*
Random rails	Average	0.81	0.84	0.16	0.015
	Maximum	0.87	0.93	0.21	0.034
	Minimum	0.73	0.73	0.11	0.008
Detail fracture rails	Average	0.79	0.86	0.18	0.017
	Maximum	0.88	0.98	0.30	0.038
	Minimum	0.70	0.72	0.12	0.008

TABLE 2.—RESULTS OF MECHANICAL TESTS ON DETAIL FRACTURE RAILS AND RANDOM RAILS

		Brinell Hardness	Yield Strength, 0.2 Percent Offset, psi.	Tensile Strength, psi.	Elong in 1 In., Percent	Reduction in Area, Percent
		Longitudinal Properties				
Detail fracture rails(44)	Average	258	66,000	130,000	12.5	15.5
	Maximum	302*	74,700	140,500	18	26
	Minimum	225	55,500	116,000	10	11
Random rails (26)	Average	257	65,800	129,500	12.3	15.5
	Maximum	278	75,400	138,000	16	21.5
	Minimum	240	55,500	118,000	9	11.5
		Transverse Properties				
Detail fracture rails(44)	Average	----------	75,400	127,000	6.4	6.8
	Maximum	----------	85,700	135,000	12.5	15
	Minimum	----------	63,800	112,500	3.5	3.5
Random rails(26)	Average	----------	71,300	124,000	5.7	6.5
	Maximum	----------	84,800	135,000	8.5	10.5
	Minimum	----------	61,400	113,500	3.5	4

*Next highest hardness was 283.

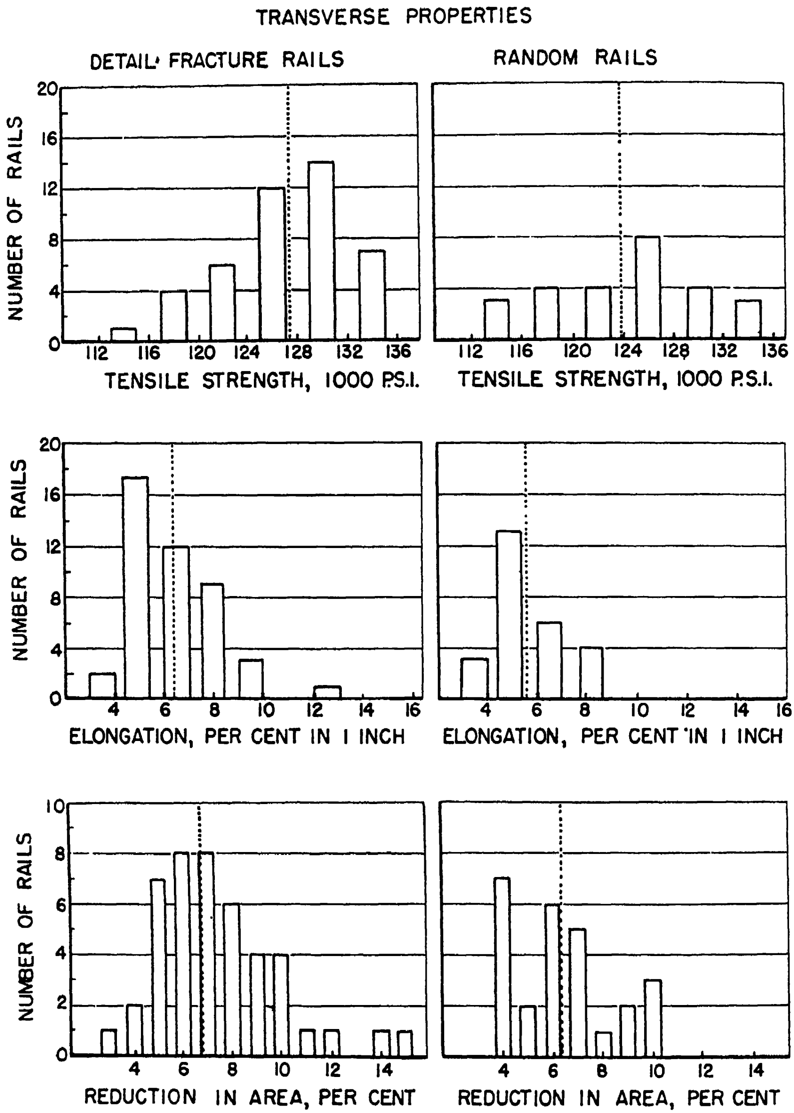


Fig. 11.—Distribution Graphs for Mechanical Properties;
Broken Lines Indicate Average Values.

below the surface as the horizontal component of the fracture. Only 6 specimens out of 46 examined (rolled since January 1, 1940) had more than the normal distribution of inclusions in this area or had a few inclusions of abnormal size. Two of the specimens examined had about one perecent or more of ferrite at the grain boundaries of the pearlite; the balance of the specimens were entirely pearlitic.

In connection with items (b) and (c) field work has been completed on stresses in tangent track, and a report by the research engineer on the work on the 132 RE rail is submitted as Appendix 11–a. A report on stress measurements in the 115 RE rail has not been completed, and the field work on stresses in the new sections on curves will be carried forward into 1950.

The report on web stresses in the 132 RE section outside the joint in tangent track shows that an adequate reduction in the web stress has been made, as compared with the 131 RE section.

The research engineer's study of the web stresses within joint bar limits in the 132 RE section indicates a satisfactory relationship between the service stresses and the fatigue life of rail steel where no unusual corrosion exists.

In connection with item (a), Professor Jensen's report, Appendix 11–b, gives the results of progress made in the investigation of corrosion fatigue and the results of work completed in the investigation of fatigue of rail web steel without corrosion, using various types of stress cycle such as are encountered within joint bar limits.

The S–N curves obtained show that for a given range of stress more damage is done by a stress which is high in tension and low in compression, than by one which is high in compression and low in tension. A completely reversed type of stress cycle, tension to compression of equal magnitude, is more damaging than a stress which ranges from high compression to low tension, and less damaging than a stress cycle which ranges from high tension to low compression.

In our previous study of stresses in the rail web outside the joint we were concerned primarily with a type of stress cycle which ranged from high compression to low tension.

The presence of the joint bars changes the stress situation within the joint bar limits because of the wedging action of the bars against the rail fishing surfaces resulting from the applied bolt tension.

Both tensile and compressive dynamic, repeated stresses are introduced by the passage of the wheel, and these are added to the static stresses maintained there by the joint bars. The resultant stresses may range from a type of stress cycle similar to that we had outside the joint, through complete reversal to a type in which the entire cycle is in the tensile part of the stress diagram. This situation is illustrated in Appendix 11–a of the report of the committee for 1948, Figs. 14 and 15, page 482 of the Proceedings, Vol. 49, 1948, and is also illustrated in Appendix 11–a of the present report.

The curves for fatigue of rail web steel without corrosion included in Appendix 11–b thus cover the type of stress cycle which is obtained in the rail web within the joint. However, studies of the frequency of occurrence of stresses of various magnitude in the rail web within the joint show relatively few cycles of stress above the endurance limits of rail web steel as shown by the above curves; in no case sufficient cycles to explain the development of failures within the life of the rail.

Fatigue Tests With and Without Corrosion

This situation was anticipated and at the same time that arrangements were set up for the fatigue tests without corrosion, arrangements were also made for fatigue tests with corrosion, using ordinary tap water as the corrosive medium. Previously, in connection with study of web failures outside the joint, corrosion-fatigue tests had been run at the University of Illinois with a stress cycle from high compression to a tension 15 percent as great, using (a) a 36-percent solution of sulfuric acid as the corrosive medium and (b) tap water. These tests were run at the ordinary speed of the testing machine.

TABLE 3.—IMPACT STRENGTHS OF DETAIL FRACTURE AND RANDOM RAILS

Temperature, deg. F.	*—50*	*0*	*80*	*212*	*400*	*500*	*600*
				Impact strengths, ft.—lb.			
Random rails							
Longitudinal	2 —4.5	2 —7	2.5—6	7.5—9.5	12.5—19.5	19—21.5	20 —22
Transverse	2.5—4	2 —4.5	3 —4.5	5 —6	9 —11.5	9—10.5	9 —10
Detail fracture rails							
Longitudinal	2 —4.5	2.5—4.5	3.5—5.5	6.5—9.5	14 —20.5	19—23	18.5—23.5
Transverse	2 —4	2.5—4	3 —5	5 —7.5	8 —12	10—14	9 —14

upper charts of Fig. 9. Within the range of hardness values obtained, there is no indication that the hardness of the rails influenced the tendency for developing detail fractures.

Tensile specimens having 1-in. gage lengths and 0.252-in. dia. in the test sections were obtained both in the longitudinal and transverse directions from the heads of the rails. Duplicate tensile specimens were tested in each case. Load-deflection curves were obtained with automatic equipment as the tensile specimens were pulled, so that the yield strengths (0.2 percent offset) could be determined. The resulting average tensile properties for both random rails (26) and detail fracture rails (44) are given in Table 2 The averages of these properties for random and detail fracture rails in both longitudinal and transverse directions are nearly the same. The distributions of these properties are shown in the charts of Figures 9, 10, and 11. The dotted vertical lines through the distribution curves represent the average values. Some variation in distribution exists for some of the properties of the random rails and detail fracture rails. However, the variations that occur do not provide a lead to the cause of the fractures and probably are not statistically significant.

Impact properties of five detail fracture rails and five random rails were determined using standard V-notch Charpy bars. The test bars were obtained in both longitudinal and transverse directions from the head sections of the rails. The tests were made in duplicate at seven different temperatures ranging from —50 deg. to 600 deg. F Since the results of the impact tests for both detail fracture rails and random rails were similar, no additional impact tests were made. Table 3 shows the ranges of the impact values.

Report on Assignment 11

Recent Developments Affecting Rail Section

C. J. Code (chairman, subcommittee), J. E. Armstrong, T. A. Blair, C. B. Bronson, W. J. Burton, E. E. Chapman, H. R. Clarke, L. S. Crane, P. O. Ferris, G. F. Hand, S. R. Hursh, C. C. Lathey, H. S. Loeffler, R. R. Manion, Ray McBrian, B. R. Myers, R. J. Middleton, R. A. Morrison, W. C. Perkins, G. A. Phillips, F. S. Schwinn, G. L. Smith.

This is a progress report presented as information.

The three topics being pursued under the above assignment are:

(a) Continuation of study of fatigue of rail web steel.

(b) Field measurement of stresses (outside the joint) in the new rail sections.

(c) Continuation of the study of web stresses within joint bar limits.

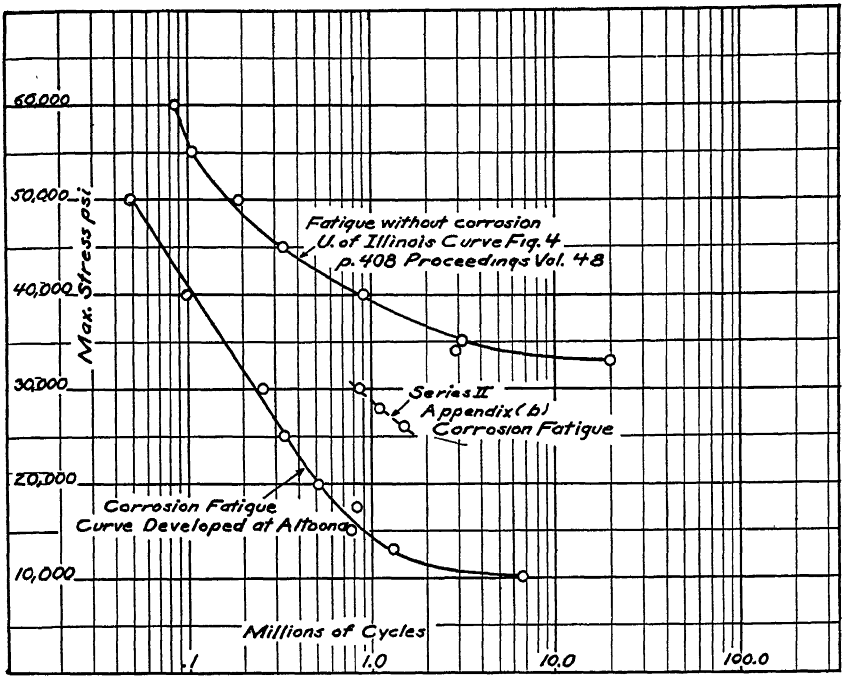


Fig. 1.—S–N Diagrams for Corrosion Fatigue and Fatigue Without Corrosion.

For example, the curve shows a fatigue life of 1,300,000 cycles at a stress of 12,500 psi., equivalent to a range of stress of 25,000 psi. A study of stresses in 131 RE rail on the Pennsylvania showed that on one worn joint in tangent track under moderately heavy traffic the rail end at the upper fillet, gage side, receiving end underwent 594,000 cycles of such stress in a year of time. This would indicate a life of only 2.2 years before cracks could be expected to develop *if sufficient corrosion were present.* If the cumulative effect of other stresses is taken into account, the equivalent number of cycles at a range of 25,000 psi. becomes 770,000 in one year, reducing the expected life to 1.7 years.

A new joint at the same location with loose bolts showed 89,000 cycles of a range of 25,000 psi. in a year, but adding the effect of other stresses an equivalent of 171,000 cycles at 25,000 psi. range. These stresses would undoubtedly increase as the rail and bars wore so that a life of somewhat less than seven years could be expected, if bolts are not kept tight.

At another location with moderate wear on rail and joint bars, and the bolts tight, an equivalent of 211,000 cycles at a range of 25,000 psi. was measured, which would indicate a life of 6 years. A considerable quantity of 1942 rail was removed at this location in 1949 due to web cracks.

Measurements made so far on 140 PS new rail, which was designed primarily to give low stress in the upper web fillet outside the joint, while they show a satisfactory stress situation within the joint where corrosion is not an important factor, do not so far indicate that sufficient improvement has been made to prevent the likelihood of failure within the joint in the normal life of the rail where abnormal corrosion exists.

The curve for the tests using 36-percent sulfuric acid showed no endurance limit, dropping straight down at about 1 million cycles, while the tests using ordinary tap water showed very little reduction in the endurance limit as obtained without corrosion. See report of the subcommittee, Appendix 12–c, pages 804 to 808.

In the meantime the chairman carried on some similar tests in the Pennsylvania Railroad laboratory at Altoona in which he ran a continuous stream of tap water on the specimens, and during which he also slowed down the speed of testing in order to prolong the test and increase the relative effect of corrosion. He obtained a greater reduction in the endurance limit than that obtained by the original procedure at the University of Illinois, for the stress cycle from high compression to low tension.

In an effort to duplicate these results the fatigue testing machines at the University of Illinois were modified to permit operation at slow speed and also to permit intermittent operation to prolong the test.

The results of preliminary tests at University of Illinois, using the slow down procedure, but continuing the practice of applying the corrosive medium at a rate of ten drops per minute were available early in the summer of 1949 and did not show any considerable reduction in the endurance limit.

A comparison of the Urbana tap water with the Altoona tap water was made, as reported by Professor Jensen, the conclusion being that the Altoona water was much more corrosive than the Urbana tap water, which probably accounted for the difference in results.

Several modifications of the procedure at Urbana were then adopted for further experiment and the preliminary results of these tests are reported by Professor Jensen in Appendix 11–b.

A curve for corrosion-fatigue with complete reversal of stress had concurrently been developed by the chairman, and is presented herewith as Fig. 1. This curve shows an endurance limit of 10,000 psi. On the same chart are plotted Professor Jensen's curve for complete reversal without corrosion and three points of Professor Jensen's tests designated as Series II in his current report. It will be observed that the curve for his Series II falls approximately half way between the curve for no corrosion and the Altoona curve.

This result (Series II of Professor Jensen's report) was obtained by using ten drops per minute of Urbana tap water modified to have the same acidity as Altoona tap water. A further modification of the University of Illinois procedure could be made by providing for a continuous flow of the modifier water. It becomes apparent, however, that by modifying the corrosion procedure sufficiently, almost any result can be obtained.

This was discussed in subcommittee and the conclusion reached that it is not worth while to pursue the subject further by making further modifications of the corrosion procedure.

Should Eliminate Corrosion Rather Than Redesign Rail

The Altoona curve for corrosion-fatigue with complete reversal of stress brings the endurance limit to such a low figure (10,000 psi.) and the fatigue life at higher stresses to such a number of cycles that service failures of rail webs within the joint. *where fairly severe corrosion is present* can be readily interpreted in terms of corrosion-fatigue failure. In fact it indicates that where such corrosion is present it becomes a practical impossibility to so design the rail and the rail joint as to prevent such failures. The most fruitful avenue of approach would seem to be in reduction of or elimination of corrosion.

in endurance limit, while still showing a fairly definite endurance limit. It is also probably a coincidence that your committee has been able to show a record of a stress history in track which predicts failure, according to the S–N curve in so nearly the length of time in which actual failure occurred.

A Reasonable Approximation of What Happens in Track

Nevertheless, this is to us the best proof that the corrosion-fatigue procedure which we adopted gives a reasonable approximation of what happens to rail web steel in track.

It was felt by the subcommittee that sufficient proof had been offered that rail web failures in the joint do occur from corrosion-fatigue, and that the fatigue life of rail web steel can be sufficiently reduced by corrosion fatigue to account for these failures. It therefore seemed unnecessary, and more or less artificial to persist in attempts at Urbana to duplicate the results obtained at Altoona. A sufficient reduction in the fatigue life has been obtained by Professor Jensen's Series II to indicate that by further modifications almost any desired S–N curve can be obtained.

It is desirable however to continue the Series II tests in order to complete the curve for complete reversal and to determine the effect on the endurance limit and fatigue life under corrosion-fatigue of two other types of stress cycle, namely, one in which stress ranges from zero to a maximum tension stress, and one which ranges from high compression to tension 15 percent as great. This work has been programmed.

The relative effect of repeated stress in the higher tensile ranges has an important bearing on the problem, with particular respect to the effect of high bolt tension. High bolt tension tends to throw the resultant of static and dynamic stress in the rail web into the tension part of the stress diagram which is generally more damaging. As far as is now known it has little other effect.

It is not to be inferred from the above that efforts to reduce the stress in the rail web, such as the recent adjustment of the bolt hole spacing are futile. Quite the contrary is true. A study of the Altoona S–N curve will show that a reduction in the stress from 17,500 psi. to 12,500 psi. will double the fatigue life, while a reduction from 12,500 to 10,000 gives five times the life, under similar conditions of corrosion.

Nevertheless, it does not appear practical at present to so reduce the stress at the first bolt hole and the upper fillet as to eliminate the possibility of premature failure under conditions of abnormal corrosion, whereas it does appear possible, by taking adequate measures to fight corrosion, to eliminate a very large percentage of such premature failures.

Failures of the type described due to corrosion-fatigue have not to the knowledge of your committee as yet developed in any of the new sections. They are comparatively rare in the 112 RE and 131 RE sections except where conditions accelerating corrosion exist. The older sections appear to have sufficient strength to resist this type of failure under ordinary conditions where corrosion is not aggravated, and the newer sections have greater strength at the critical areas. No anxiety need be felt with respect to failures of this type except where some condition exists which causes excessive corrosion

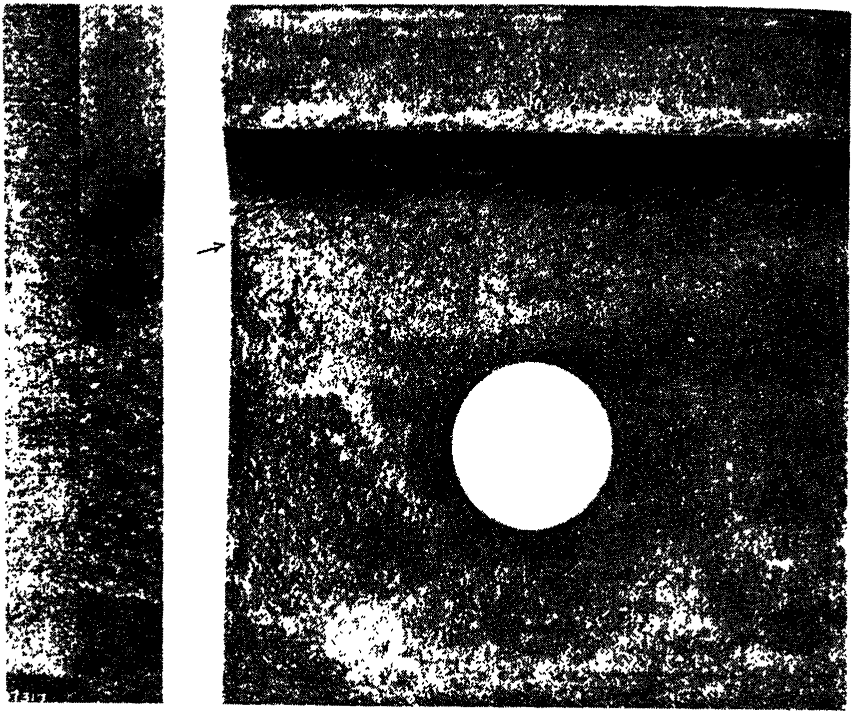


Fig. 2.—Laboratory and Field Specimens.

It may well be asked what relationship the type of corrosion applied to the laboratory specimens bears to that experienced in the field. The question is difficult to answer directly. The laboratory test is of necessity an accelerated test both as to the frequency of stress application and as to corrosion. No rail end in track has a continuous stream of water played on it, but rail ends in the vicinity of water pans are sprayed with water so frequently that they are continuously wet.

The time factor is of course much greater in service, a specimen which is brought to failure in ten days in the laboratory, lasting as many years in track. The total time during which a rail is subjected to moisture in track is undoubtedly often greater than the total duration of the laboratory test.

In some locations condensation leaves the rails wet almost every morning and if this is combined with a corrosive atmospheric condition such as exists in many industrial districts, corrosion is bound to be severe. Certain types of lubricant applied to rail ends have been found to retain moisture.

The appearance of the rail ends which have developed cracks has been found to coincide very closely with the appearance of a specimen which has undergone corrosion-fatigue in the laboratory. Both are characterized by sharp elongated pits and by a multiplicity of cracks, rather than the one crack which is characteristic of an ordinary fatigue failure. This is illustrated by Fig. 2.

It may be taken as a fortunate coincidence that the Altoona tap water has such corrosive properties as to produce, an S–N curve which shows such a marked reduction

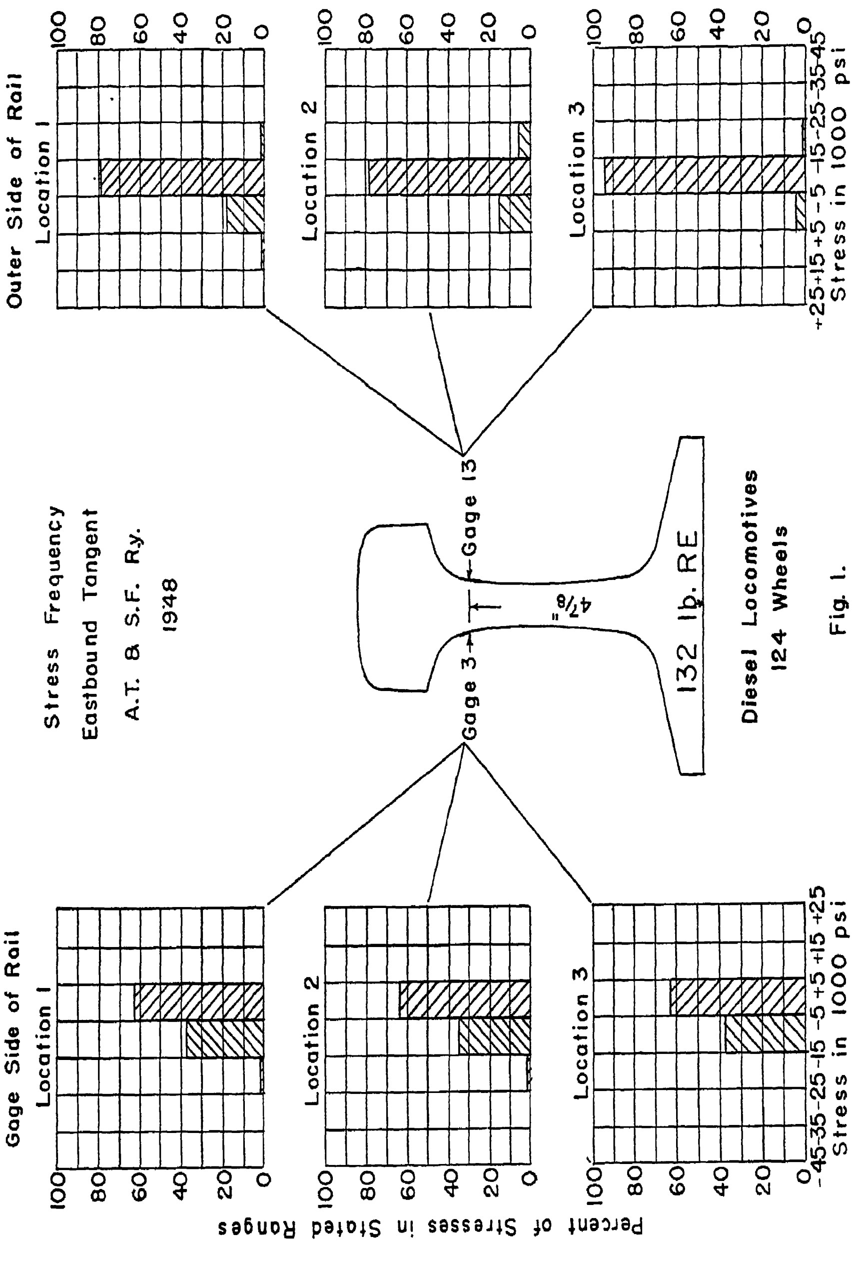

Stress Frequency
Eastbound Tangent
A.T. & S.F. Ry.
1948
Outer Side of Rail
Location 1
Location 2
Location 3
Gage Side of Rail
Location 1
Location 2
Location 3
Gage 3
Gage 13
4 7/8"
132 lb. RE
Diesel Locomotives
124 Wheels
Percent of Stresses in Stated Ranges
Stress in 1000 psi
+25 +15 +5 -5 -15 -25 -35 -45
-45 -35 -25 -15 -5 +5 +15 +25
100
80
60
40
20
0

Fig. 1.

Appendix 11-a

Measurements of Stresses in 132 RE Rail on Tangent Track—Santa Fe Railway

Web Stresses in the New 132 RE Rail Section

As described in the report on Assignment 7, in August 1948 the Atchison, Topeka & Santa Fe Railway, in laying new 132 RE rail in the eastbound main track 100 miles west of Chicago, installed service test sections of joint bars for the new rail section, each one-half mile in length on tangent track. Included in these test sections were three locations with the new AREA headfree joint bars 36 in. in length, having, respectively, the old AREA 6-hole bolt spacing, the new AREA spacing and an experimental spacing providing only four bolts for a 36-in. bar. Specifically these three test sections are as follows:

Location V, new AREA design, headfree 36-in. joint bar for 132 RE rail, with bolt spacing of 3½–6–6 in.

Location W, same joint bar design with bolt spacing of 4½–9 in. (4 bolts in the 36-in. joints.)

Location X, same joint bar design with bolt spacing of 2½–6½–6½ in.

This installation offered an opportunity to obtain measurements of stresses developed under regular traffic in the new 132 RE section with respect to the following:

A. To determine to what extent the service stresses in the upper web and upper rail fillets had been reduced with the new rail design.

B. To obtain information on the range of stress developed by traffic for correlation with the fatigue strength tests being carried out in the laboratory of the University of Illinois.

C. To obtain information on the effect of bolt hole spacing on the range of web stresses developed in service.

The measurements, analysis of data, and preparation of the report for these tests were made by the Engineering Division research staff of the Association of American Railroads, under the general direction of G. M. Magee, research engineer, by M. F. Smucker, assistant electrical engineer, and Olaf Froseth, assistant track engineer, assisted by other staff members.

Previous reports of the committee have described the high stresses that were found in the old 112 RE and 131 RE rail sections in the upper portion of the rail web and in the upper rail fillets. It was pointed out that these were due to stress concentration effects from the wheel-bearing pressure and were aggravated by the bending of the head on the web because the wheel load was frequently applied eccentrically, generally toward the gage corner. In the design of the new 115 and 132 rail sections the upper part of the web was thickened and longer fillet radii were used. Laboratory tests indicated this modification would effect a stress reduction of approximately 25 percent. In addition, the top of the rail was rounded to relieve the gage corner from excessive bearing pressure and bring the point of contact between wheel and rail more nearly to the center of the head.

The stress measurements were conducted at three different locations in the track. At Location 1 the stress gages were placed half way between ties and at the other two locations the gages were positioned directly over the same tie on opposite rails. Stresses

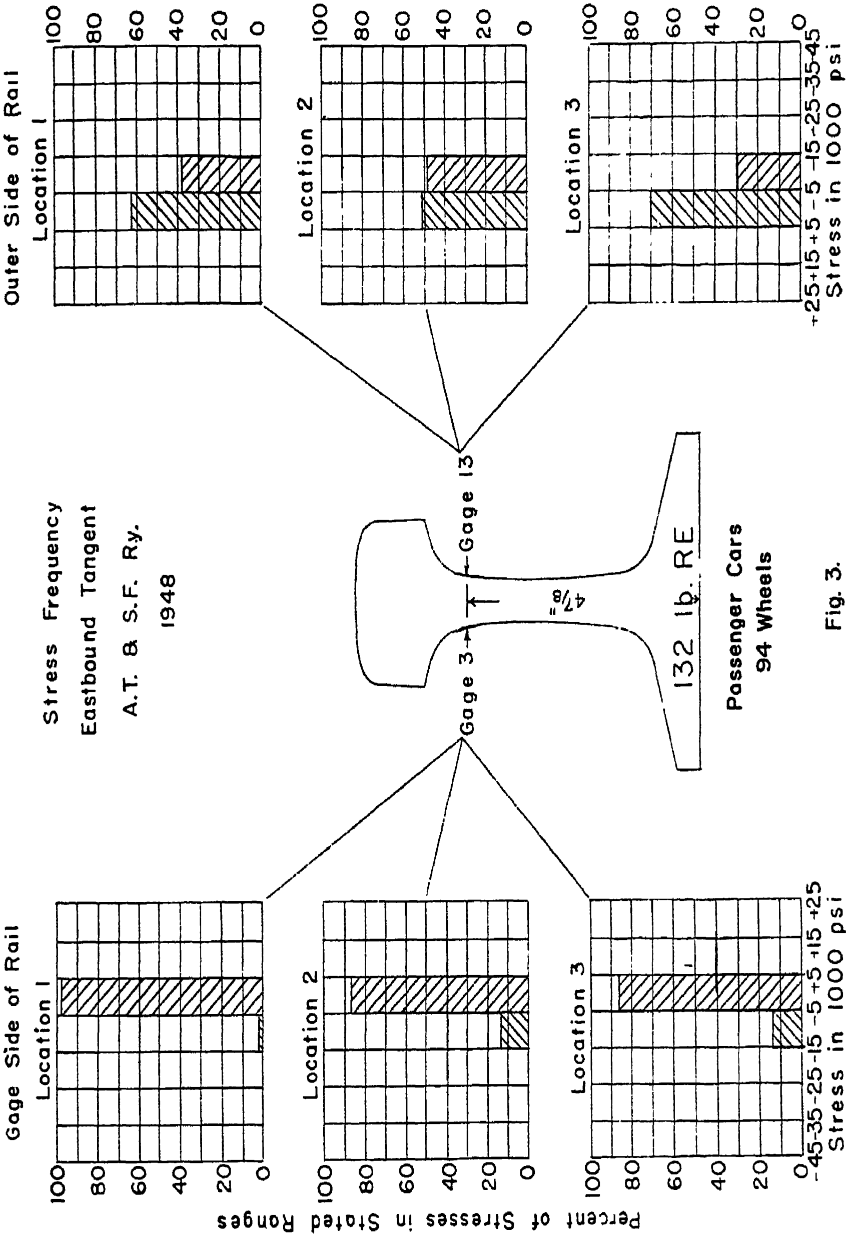

Stress Frequency
Eastbound Tangent
A.T. & S.F. Ry.
1948
Outer Side of Rail
Location 1
Location 2
Location 3
Gage Side of Rail
Location 1
Location 2
Location 3
Gage 3
Gage 13
4 7/8"
132 lb. RE
Passenger Cars
94 Wheels
Percent of Stresses in Stated Ranges
100
80
60
40
20
0
Stress in 1000 psi
+25 +15 +5 -5 -15 -25 -35 -45
-45 -35 -25 -15 -5 +5 +15 +25

Fig. 3.

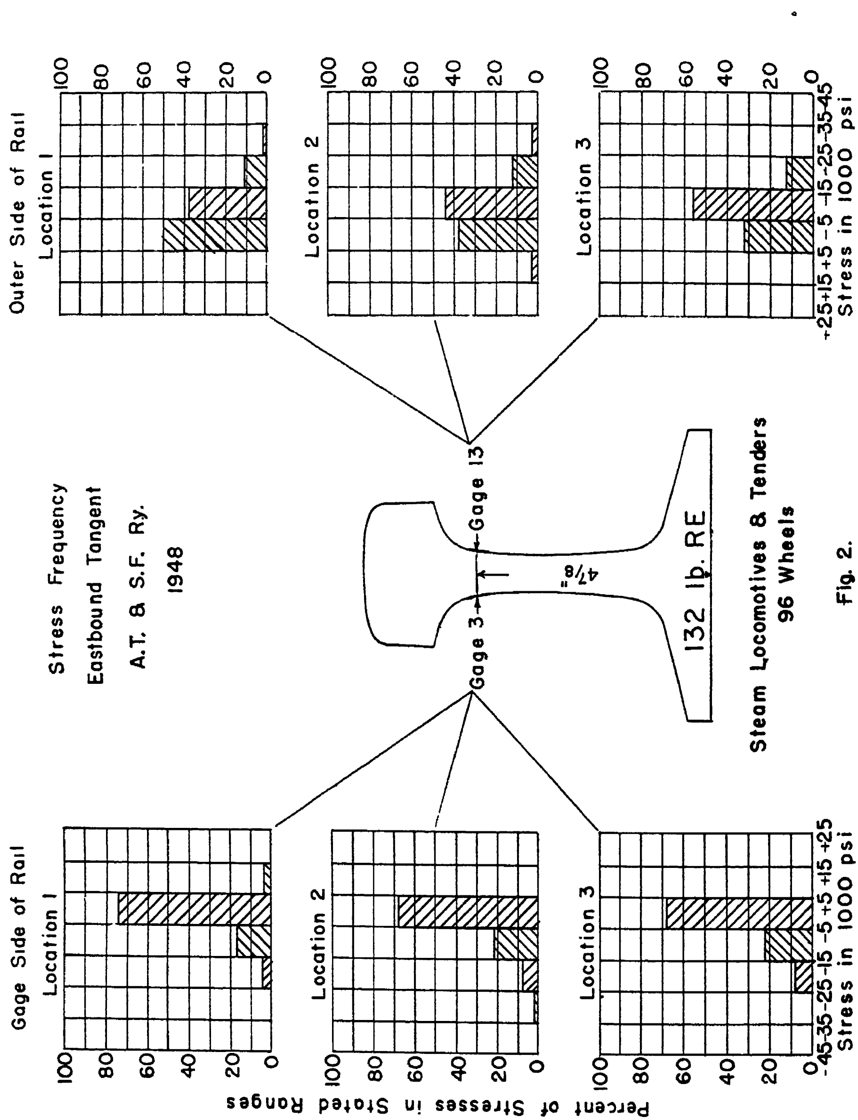

Stress Frequency
Eastbound Tangent
A.T. & S.F. Ry.
1948
Outer Side of Rail
Location 1
Location 2
Location 3
Gage Side of Rail
Location 1
Location 2
Location 3
Gage 13
Gage 3
$4\frac{7}{8}$"
132 lb. RE
Steam Locomotives & Tenders
96 Wheels
+25 +15 +5 -5 -15 -25 -35 -45
Stress in 1000 psi
-45 -35 -25 -15 -5 +5 +15 +25
Stress in 1000 psi
100 80 60 40 20 0
Percent of Stresses in Stated Ranges

Fig. 2.

were measured only near the upper web fillets on the gage and field sides of the rail, as previous tests had shown these to be the areas of highest stress. (See Fig. 1.) Fortunately, regular train operation over this track included both steam and diesel locomotives and passenger and freight trains, covering a speed range to almost 100 mph.

Figs. 1 to 4, incl., show the results obtained from the measurements. These charts were prepared to show the percentage of stresses occurring within a given stress range for diesel and steam locomotives separately and for passenger and freight cars separately. The diagrams were prepared in this manner so that the stress frequency to be anticipated for any traffic conditions could be estimated from these data. As the wheel loads experienced in these tests are representative of those normally encountered on almost any main line railroad, the results obtained in these tests provide a reasonably accurate picture of prevailing stress frequency.

It will be observed that with this improved rail section on tangent track the stress range is well balanced on both the gage and field sides, and for diesel locomotives and both passenger and freight cars the stress range lies mostly between 5000 psi. tension and 15,000 psi. compression. For steam locomotives the stress range is also well balanced on both field and gage sides, but is somewhat larger, lying mostly between 5000 psi. tension and 25,000 psi. compression. Measurements at the same position on the rail web on the old 131 RE section on tangent track on the Norfolk & Western Railway showed a stress range on the gage side from 35,000 psi. compression to 5000 psi. tension, with occasional stresses going as high as 55,000 psi. compression. On the field side the stress range was principally from 25,000 psi. compression to 15,000 psi. tension, with some stress values going as high as 45,000 psi. compression and 25,000 psi. tension. These stresses were measured under steam locomotives and were reported in AREA Proceedings Vol. 48, 1947, page 777. Comparison of the stress range obtained with the 132 RE section relative to that of the 131 RE indicates that a very substantial improvement has been effected in the range of fillet stress with the revised design on tangent track. Stress measurements have not as yet been made on the 132 RE section on curved track, but this is planned for 1950.

Web Stresses within Joint Bar Limits

In AREA Proceedings Vol. 49, 1948, page 464, a complete report was given of laboratory tests conducted at the University of Illinois by the research staff with three different bolt spacings for the new 115 RE rail section. As a result of the data obtained in these tests, the Association adopted a revised bolt hole spacing of 3½–6–6 in. in lieu of the old spacing of 2½–6½–6½ in. Laboratory tests indicated that the new spacing effected substantial reductions in the rail web stress in the upper fillet at the rail end and at the first bolt hole. It was also shown in these laboratory studies that the applied bolt tension alone is responsible for a substantial web stress, which is referred to as the static web stress. Dynamic stresses result from passing wheel loads and the flexure of the joint.

The installation on the Santa Fe afforded an opportunity to obtain measurements in the field with the new and old bolt spacings for the new 132 RE section. Also, because of the interest expressed by various railways in the possibility of using a 36-in. joint with only four bolts and the inclusion of this type of spacing in the test installation, an opportunity was afforded to obtain stress measurements with 4½–9 in. bolt spacing. Accordingly, rail web stress measurements were made in November 1948 at two joints with the AREA headfree design bars for each of the three different bolt spacings. These measurements included the dynamic stresses developed in the rail web under regular service trains. Measurements were made near the upper and lower fillets and at the

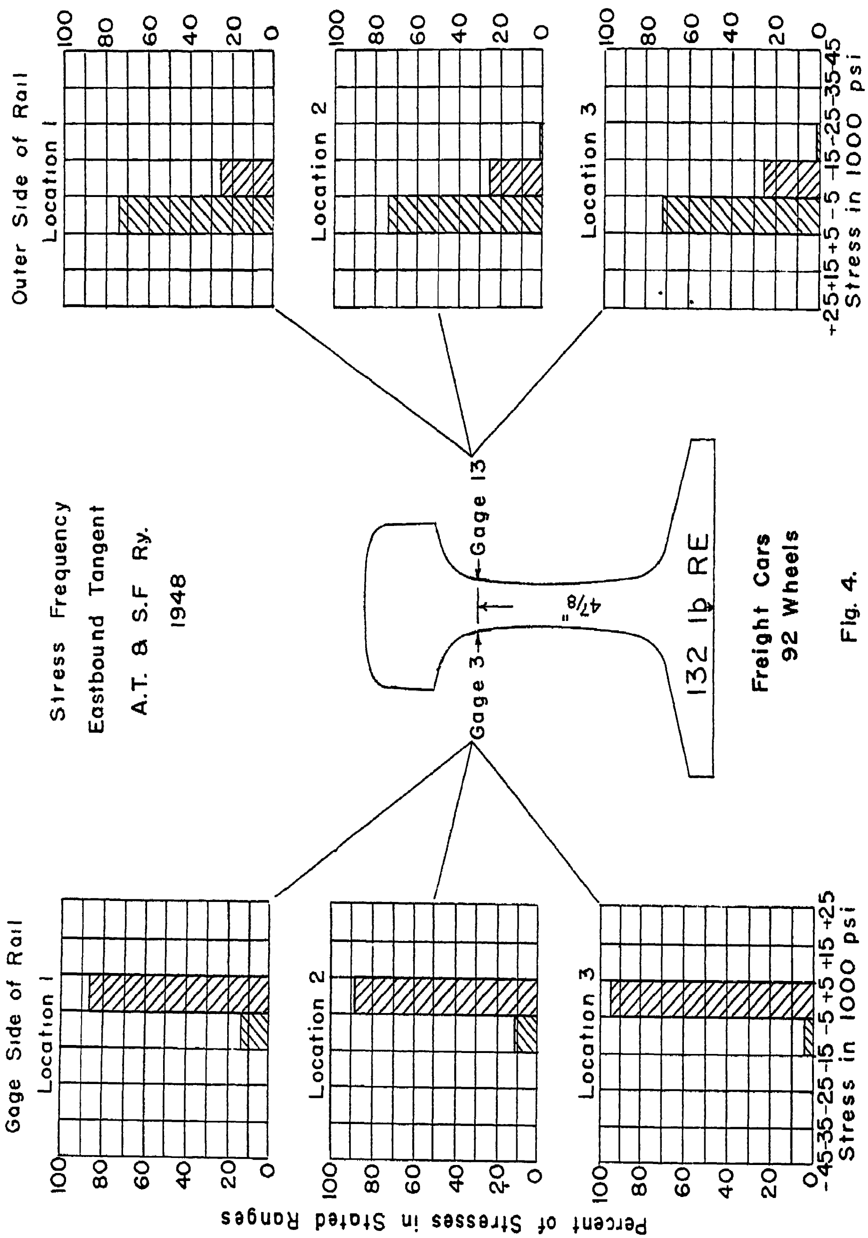

Stress Frequency
Eastbound Tangent
A.T. & S.F Ry.
1948
Outer Side of Rail
Gage Side of Rail
Location 1
Location 2
Location 3
Gage 13
Gage 3
4 7/8"
132 lb RE
Freight Cars
92 Wheels
Stress in 1000 psi
Percent of Stresses in Stated Ranges
100
80
60
40
20
0
+25 +15 +5 -5 -15 -25 -35 -45
-45 -35 -25 -15 -5 +5 +15 +25

Fig. 4.

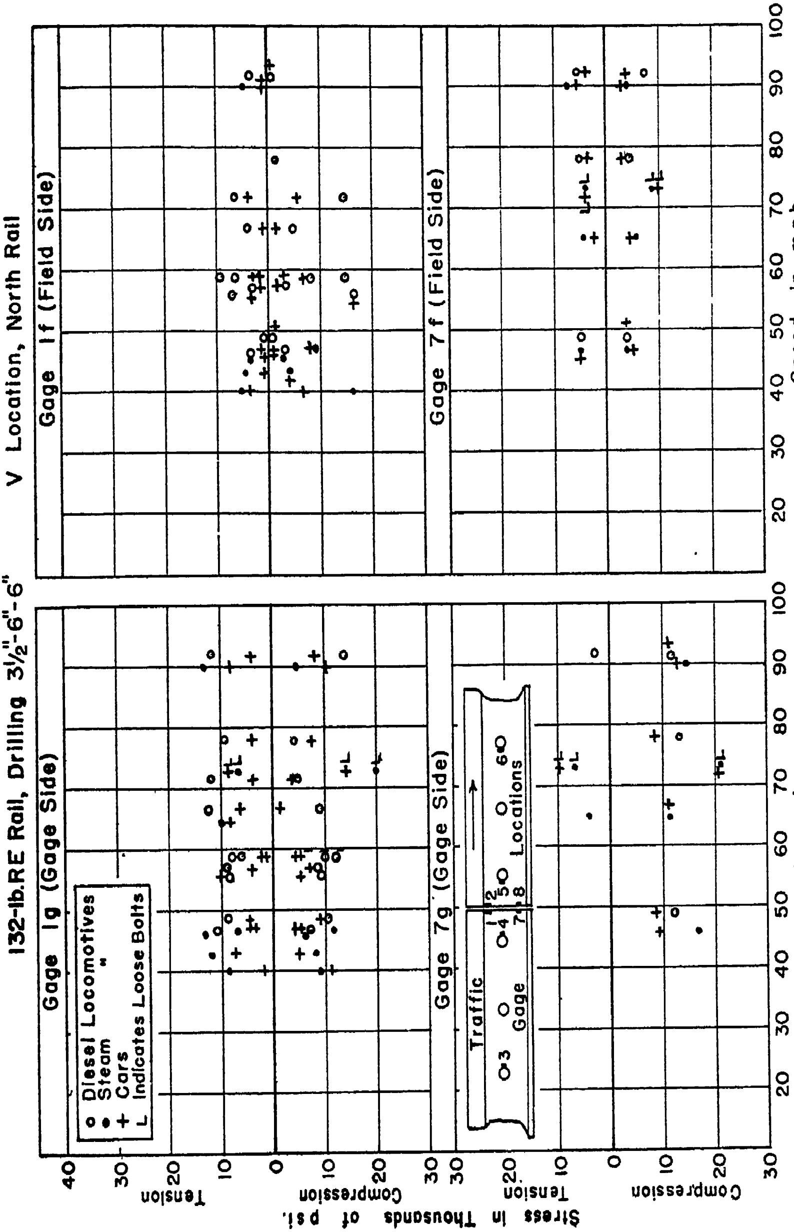


Fig. 5.—Maximum Dynamic Rail Web Stresses at Gages 1 and 7. Joint V-2, A.T.&S.F. Ry.

first and last bolt holes on each rail end at the joint and on both the field and gage sides. In September 1949 the static stresses due to the applied bolt tension only and not including dynamic stresses were made at six joints for each bolt spacing in the upper fillet and at the first bolt hole for each rail end at the joint on both the field and gage sides.

Discussion of Dynamic Stresses

Figs. 5 to 7, incl., show the maximum tension and compression stress during each test run obtained at one joint with the new spacing (3½–6–6 in.) on the north rail. The chart shows the stresses for diesel and steam locomotives separately and also those developed under the cars. Values are plotted with respect to the speed of the train and the diagram shows the location at the rail end for each numbered gage, providing a convenient means of identification. It will be observed from these figures that there is no definite trend for change in stress range or increase in stress with increase in speed. In fact there appears to be no apparent relation between stress and train speed within the speed range covered—from 40 to almost 100 mph. In general, the range of stress does not appear to be high relative to the fatigue strength that may be expected of the rail steel. Some tests were made in which the bolts were intentionally left loose and for these runs, in general, considerably higher stresses were obtained, as shown in the diagrams. Similar diagrams were prepared for each of the six joints included in these dynamic tests, but are not reproduced, inasmuch as the general pattern of stresses obtained corresponds to those shown in these three diagrams.

A better visual comparison of the dynamic stresses is afforded by Fig. 8, in which the average maximum for each run and the single maximum stress obtained are shown for the two joints of each different rail drilling. It is interesting to note that the range of stress at the receiving rail end is somewhat higher than for the leaving end, particularly in the upper and lower fillets and at the first bolt hole. There does not seem to be a very pronounced difference in range of stress with respect to the three different bolt spacings included, but what difference there is, is in favor of the new spacing of 3½–6–6 in.

Correlation of Measured Stresses with Laboratory Fatigue Data

From the standpoint of the development of fatigue failures, the actual stress, or the combination of stresses due to bolt tension and passing wheel loads, is most significant. The measurements of static stress have shown that the static or initial stress applied in the rail web due to the bolt tension is quite variable. A bending may be set up in the rail web due to the manner in which the joint bars fit into the fishing surfaces and as a result the stress at any individual gage location may vary from a low to a very high tension. This means, therefore, that for any specific location within the joint bar, the actual dynamic stress range may be from a high tension to a low compression, equal tension to equal compression, high compression to low tension or any value in between.

In Appendix 11–b are presented the results of fatigue tests conducted by Professor R. S. Jensen in the laboratory at the University of Illinois. In these tests, specimens of rail steel taken from the rail web were tested and the fatigue strength determined for various ranges of applied stress. The results of these tests are shown in Fig. 9 in the form of a Goodman diagram. From this diagram it is then possible to determine what range of dynamic stress may be tolerated for any initial static stress developed by the applied bolt tension.

Table 1 shows for both the upper fillets and the first bolt holes the maximum static stress that was measured in any of the six joints tested at each location (V, W or X)

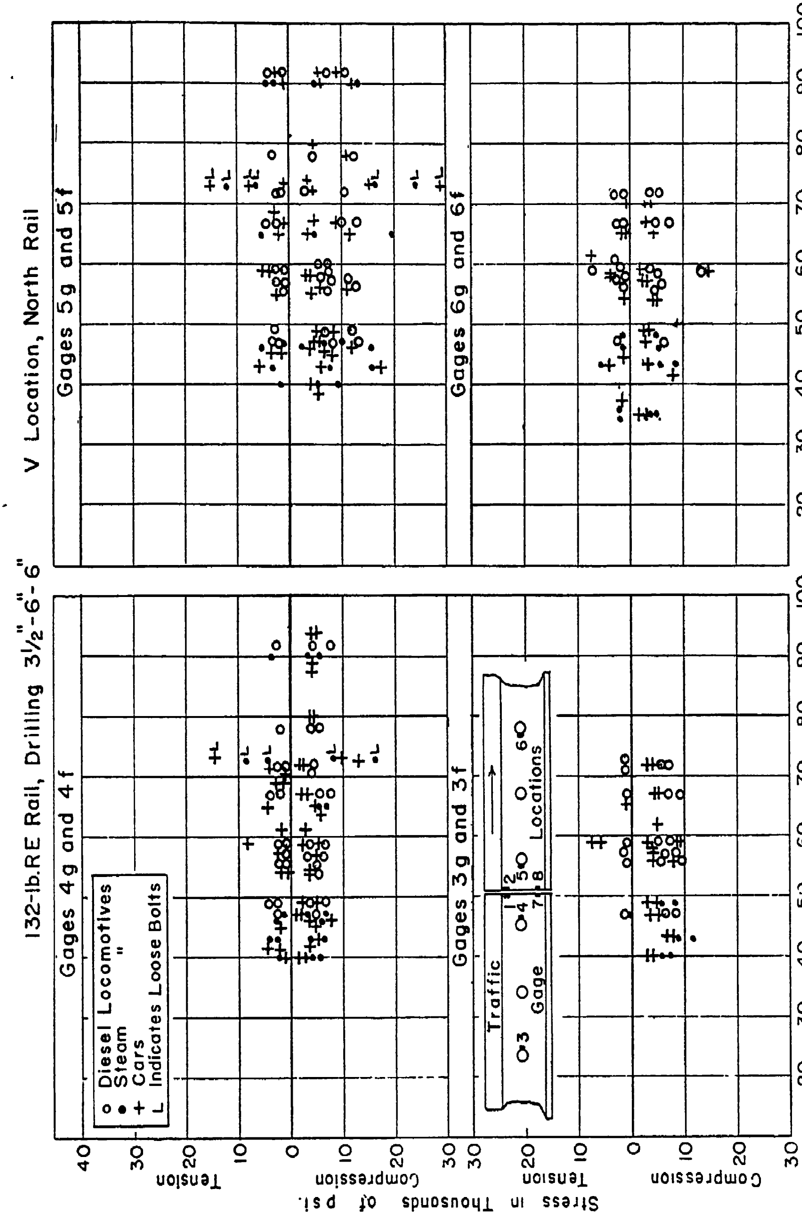


Fig. 7.—Maximum Dynamic Rail Web Stresses at Gages 3, 4, 5 and 6. Joint V-2, A.T.&S.F. Ry.

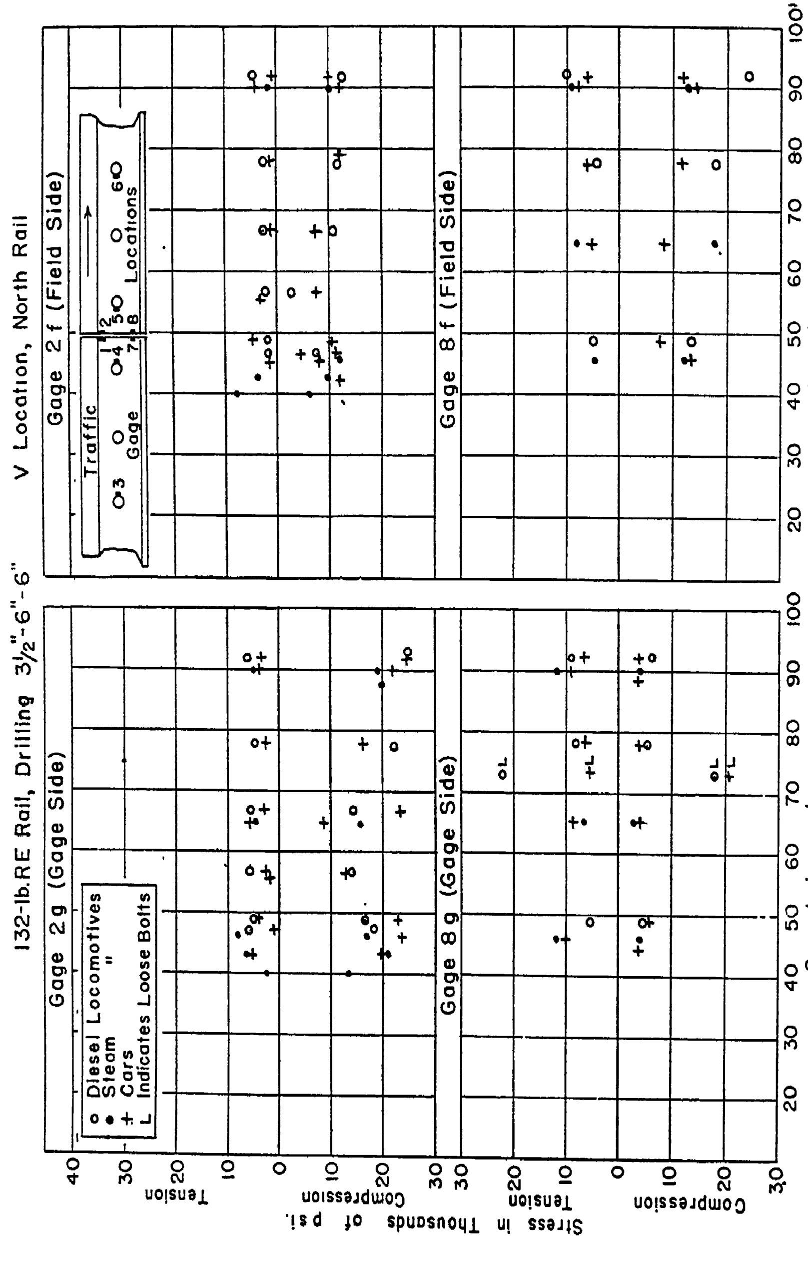


Fig. 6.—Maximum Dynamic Rail Web Stresses at Gages 2 and 8. Joint V-2, A.T.&S.F. Ry.

TABLE 1.—RAIL WEB STRESS IN THE VERTICAL DIRECTION WITHIN JOINT BAR LIMITS
Santa Fe Railway Tests of 132 RE Rail Section—Tangent Track
(Stresses are given in pounds per square inch)

	Upper Fillets			First Bolt Hole		
Location	*Max. Static Stress*	*Range of Dynamic Stress*	*Range of Fatigue Strength*	*Max. Static Stress*	*Range of Dynamic Stress*	*Range of Fatigue Strength*
V	+12,000	28,000	61,000	+29,000	17,000	50,000
W	+ 9,000	28,000	62,000	+28,000	12,000	51,000
X	+18,000	32,000	57,000	+40,000	24,000	45,000

with the different bolt spacings. In the adjoining column is shown the maximum range of dynamic stress that was found at this particular gage location. This range was taken as the average of the maximum stresses obtained in each run rather than the single maximum for the reason, as previously explained, that the single maximum stress values would not be expected to occur with sufficient frequency to occasion a fatigue failure.

For comparison with the values of dynamic stress as they were measured in the field, are shown the values for the fatigue strength of the steel as obtained in the laboratory tests and shown in Fig. 9. It will be observed that for the new 132 RE rail section

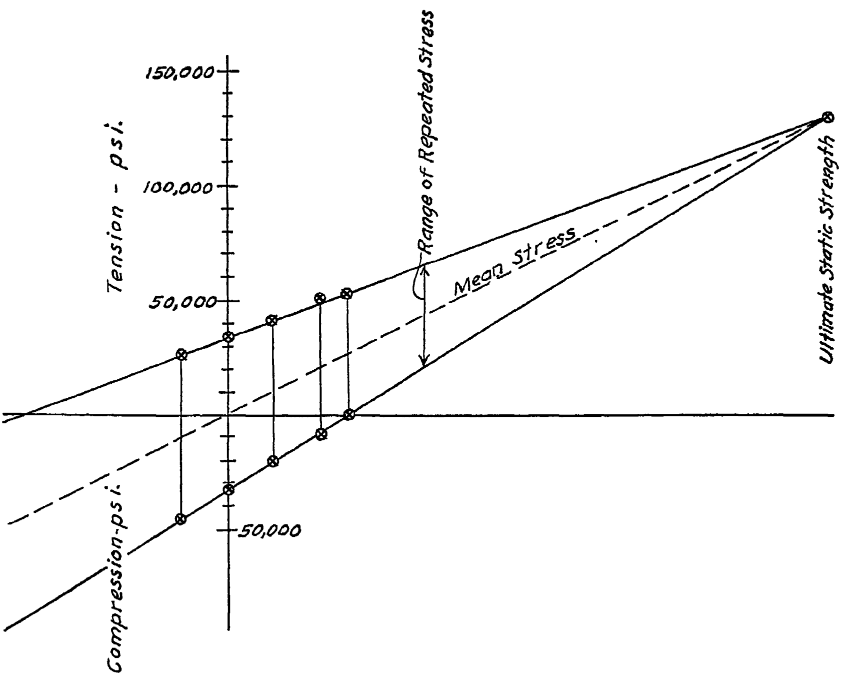
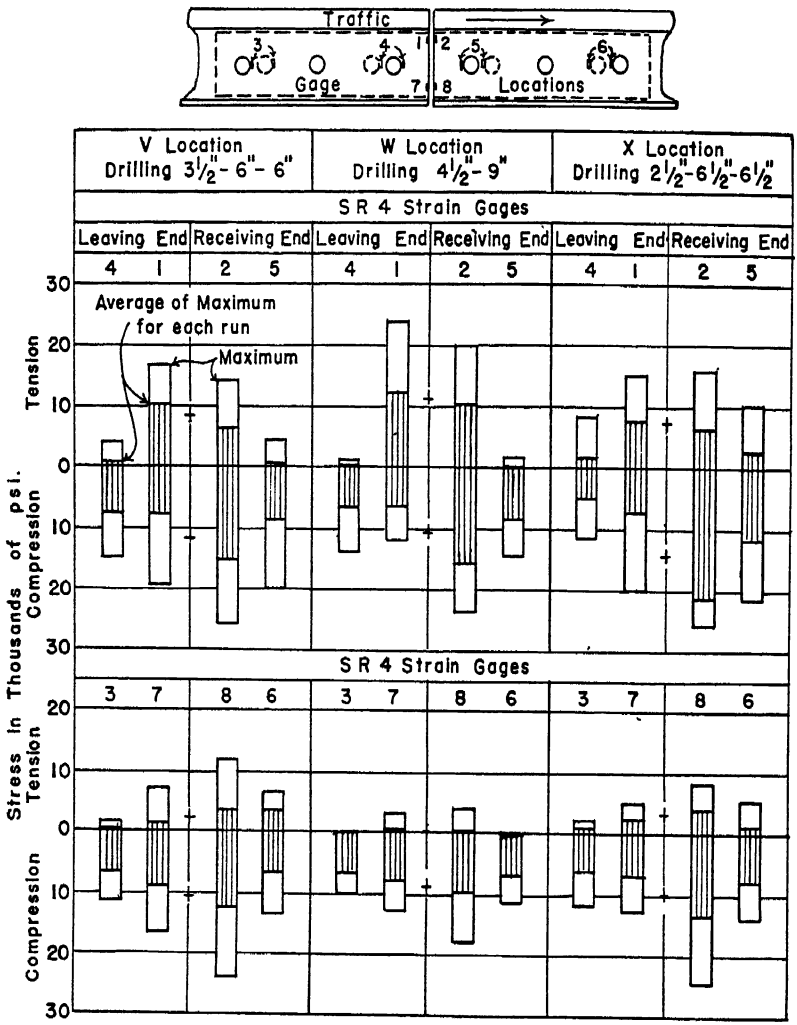


Fig. 9.—Fatigue Strength of Rail Web for Various Ranges of Stress as Determined by Laboratory Tests (As Rolled Surface without Corrosion).

A



Note: Average stress values are the mean of gage and field side stresses produced by locomotives in two rail joints at each location.
+ Indicates average of Leaving and Receiving end stresses in gages 1 and 2, 7 and 8.

Fig. 8.—Dynamic Stresses in Rail Web at Joints of 132 RE Rail, A. T. & S. F. Ry.

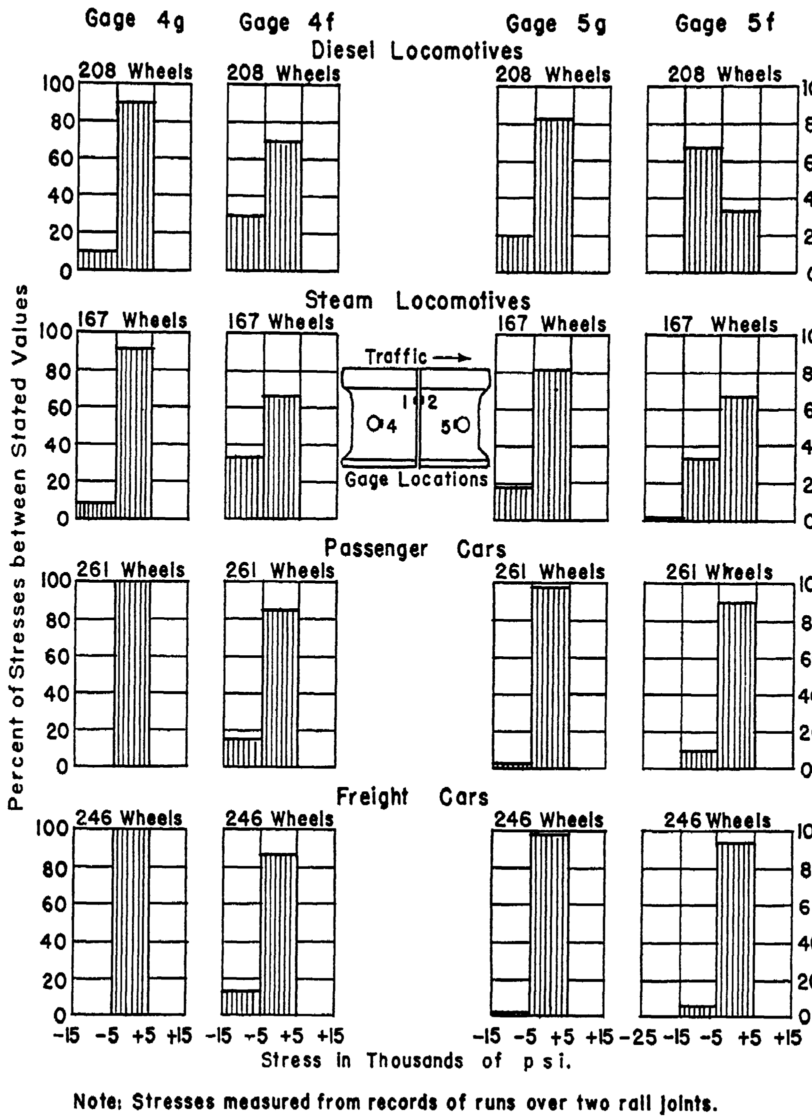
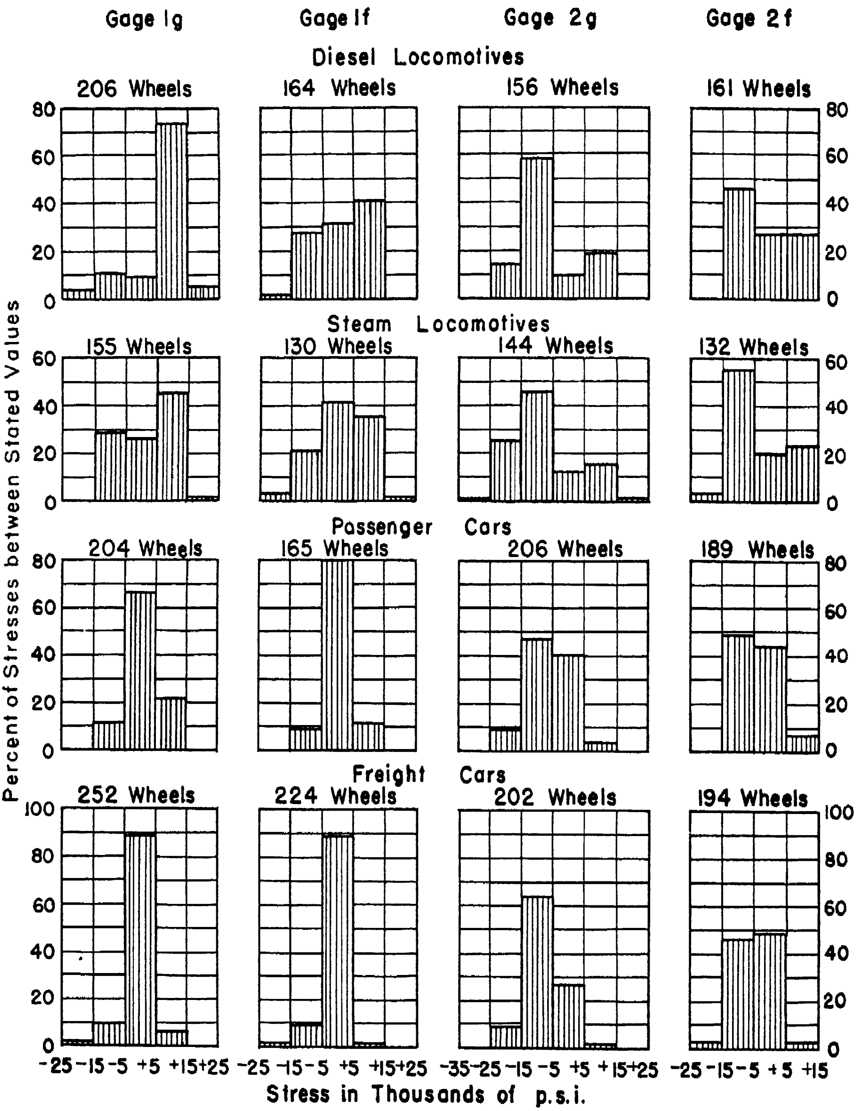


Fig. 11.—Frequency of Occurrence of Dynamic Stresses in Rail Web at First Bolt Holes from Rail Ends. V Location, A. T. & S. F. Ry.



Note: Position of SR 4 Strain Gages 1 and 2 shown on Fig. 11.
Stresses measured from records of runs over two rail joints.

Fig. 10.—Frequency of Occurrence of Dynamic Stresses in Upper Part of Rail Web of Rail Joints. V Location, A. T. & S. F. Ry.

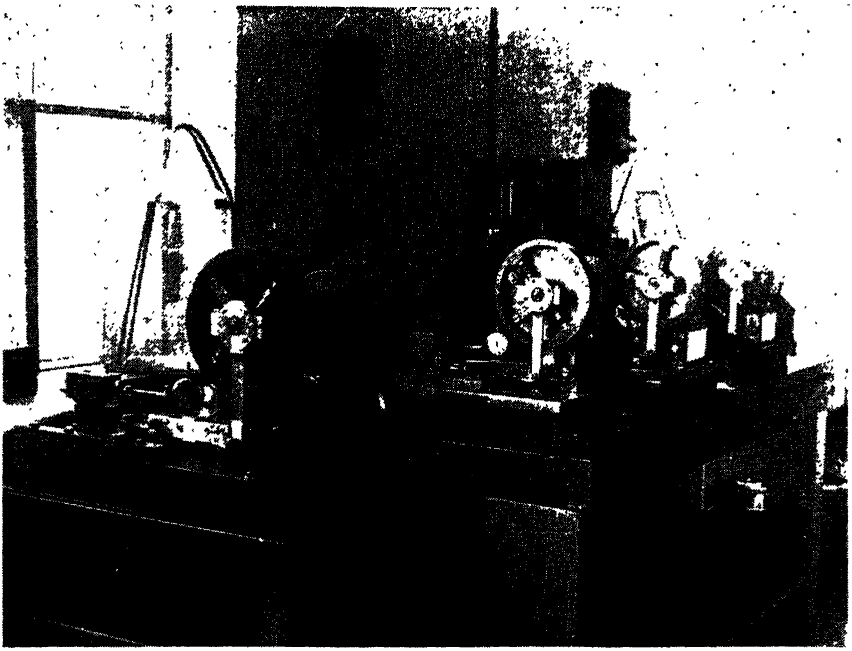


Fig. 1.—Vibratory Type Fatigue Machines.

TABLE 1.—PHYSICAL PROPERTIES OF RAIL WEB STEEL

Specimen No.	*Tensile Strength psi*	*Yield Strength 0.2 percent set psi*	*Reduction of Area Percent*	*Elongation 2 in gage length Percent*
1*	136,200	77,600	16.3	9.5
2	137,200	78,300	16.5	10.0
3	137,700	78,500	15.5	10.0
Avg.	137,033	78,133	16.1	9.8
4**	137,500	79,800	17.9	11.5
5	137,000	79,800	18.4	11.0
6	137,000	79,400	16.4	11.5
Avg.	137,166	79,666	17.5	11.3

*Specimens 1, 2 and 3 taken parallel to direction of rolling.
**Specimens 4, 5 and 6 taken transverse to direction of rolling.

Previous studies of the fatigue of rail webs in the laboratory indicated a fatigue life several times greater than was actually obtained in service at some locations. Since corrosion of the rail web was quite heavy at the locations where early service failures occurred, it was thought that the discrepancy which existed between laboratory tests and service life was due mainly, if not entirely, to corrosion.

Laboratory corrosion-fatigue tests[1] using tap water and with the machines operating at their normal speed of 1.1 million cycles per day, gave endurance limits only slightly

[1] AREA Proceedings, Vol. 48, 1947, pp. 804–808.

and the new AREA bolt spacing (Location V) the range of dynamic stresses is only about one-third of the fatigue strength of the steel as determined from the laboratory tests. As further information, Figs. 10 and 11 show the frequency of occurrence of dynamic stresses as determined in the field measurements. These diagrams show the stresses in the upper fillet at the rail end and at the first bolt hole which past measurements have shown to be the high stress areas. From these diagrams it will be observed that at any specific gage location the maximum stress range at which there would appear to be a sufficient frequency of stress to produce fatigue failure does not exceed 30,000 psi. Accordingly, it is evident that on tangent track with the 132 RE improved design of rail section and the new bolt hole spacing, there is sufficient fatigue strength to resist the development of fatigue cracks, provided there are no unusual corrosive factors present which would tend to lower the fatigue strength of the rail steel substantially.

Conclusions

From these tests conducted on tangent track under conditions typical of main line operation, it may be concluded:

(a) That the stresses in the upper rail fillets on tangent track outside of the joint bar limits have been reduced with the new 132 RE section to well within the fatigue strength of rail steel, and

(b) That the concentrated rail web stresses within joint bar limits at the rail end and at the first bolt hole with the new 132 RE rail section and new AREA bolt spacing are well within limits that can be tolerated, provided no unusual corrosion conditions exist that substantially reduce the fatigue strength of the rail steel.

Appendix 11-b

Fatigue Tests of Rail Webs

By R. S. Jensen

Special Research Assistant Professor of Engineering Materials, University of Illinois

Introduction and Acknowledgment

The study of the fatigue strength of rail webs has been continued. As reported in previous AREA Proceedings, T-section specimens with as-rolled surfaces were cut from the web of a 112 RE rail and tested as cantilever beams in flexure. Fig. 1 shows four vibratory type fatigue machines used for the tests, and two electric timers which can be set to operate the machines automatically either intermittently or continuously.

In addition to the fatigue specimens, two sets of tensile specimens were cut from the webs of the rails; one set parallel to direction of rolling, and the second set transverse to direction of rolling. Physical properties of the rail web steel as determined by these tensile tests are listed in Table 1. Only slight differences in the physical properties of the two groups of specimens were disclosed.

Acknowledgment is made of the services of Frank Suter, special research graduate assistant, who conducted part of the corrosion-fatigue tests.

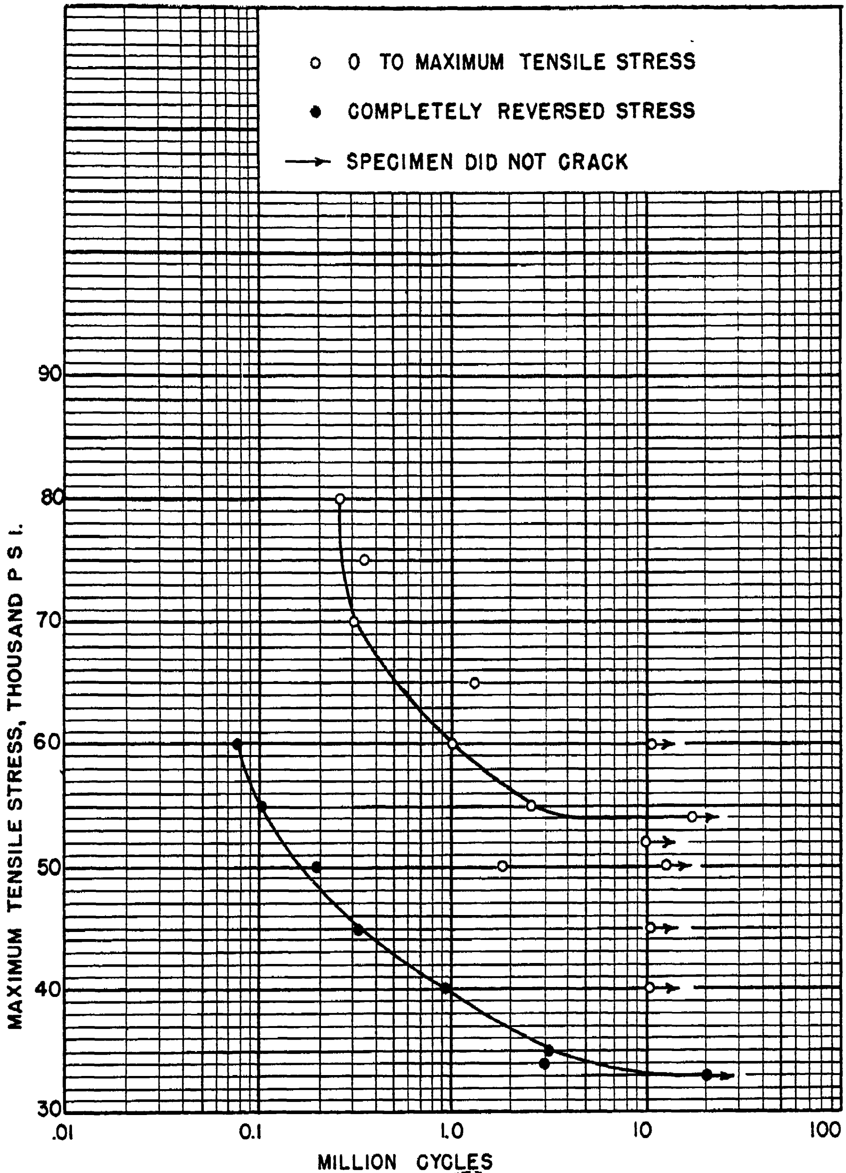


Fig. 3.—S-N Diagrams for Fatigue Tests of Rail Webs.

lower than for specimens with no corrosion. Although tap water was a relatively mild corroding agent, it was thought that the time element was largely responsible for the small decrease in fatigue life under corrosion. Therefore, further corrosion-fatigue tests were planned in which it was proposed to run the machines at 150 rpm., instead of 800 rpm. and to limit their operating time by electric timers, set to run the machines only a few minutes of each hour, in order to prolong the time the specimens were subject to corrosion.

At the suggestion of C. J. Code, chairman of Subcommittee 11, a series of laboratory fatigue tests was outlined, simulating stress conditions in the rail webs in service both within joint bar limits and outside the joint bars. For each range of stress, two series of tests were proposed, one series with no corrosion on the specimens, and another series with tap water as the corroding agent and the machines running 10 min. of each hour to prolong the corrosion on each specimen to approximately one week instead of only several hours.

Results of Tests

The diagrams of Fig. 2 show the types of stress cycles to which the specimens were subjected.

Figs. 3 to 6 show the S–N diagrams for the tests completed to date with no corrosion on the specimens. These ranges of stress correspond to ranges encountered in service within joint bar limits. The upper curve of Fig. 3 is for a range of stress from zero to a maximum tensile stress and indicates an endurance limit of 54,000 psi. The lower curve of Fig. 3 is for a range of completely reversed stress and indicates an endurance limit of 33,000 psi. The curve of Fig. 4 for a mean compressive stress of 10,000 psi. indicates an endurance limit of 46,000 psi. and the curve of Fig. 5 for a mean tensile stress of 10,000 psi. indicates an endurance limit of 42,000 psi. These latter two curves indicate that tensile stresses tend to lower the endurance limit more than compressive stresses.

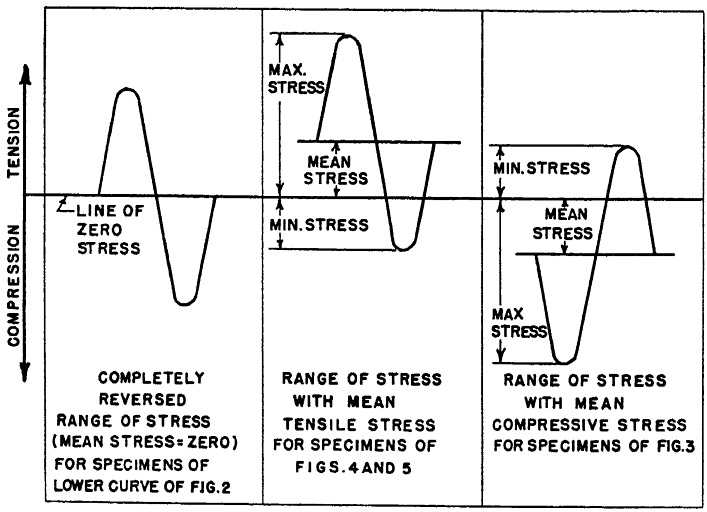


Fig. 2.—Diagrams for Varying Range of Stress.

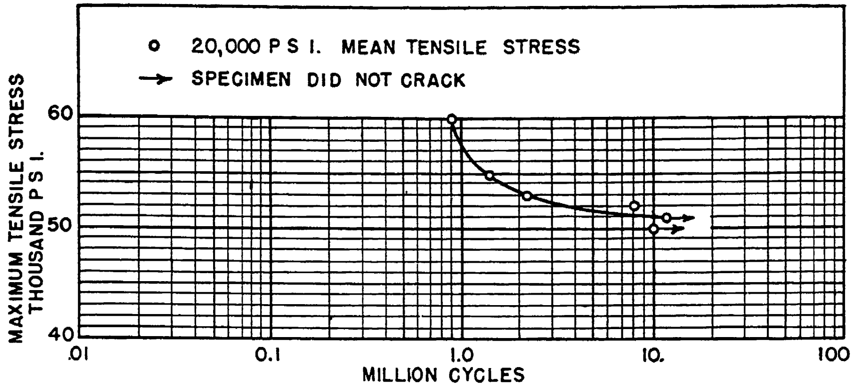


Fig. 6.—S-N Diagram for Fatigue Tests of Rail Webs.

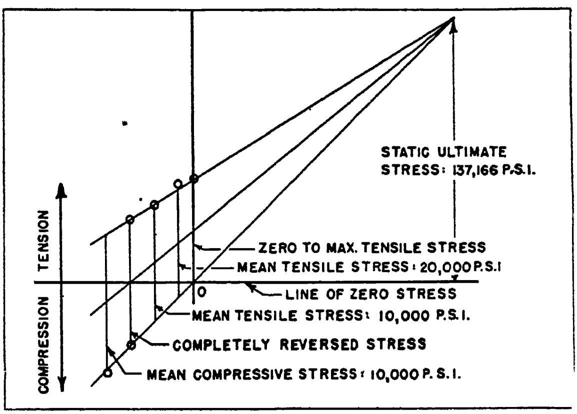


Fig. 7.—Modified Goodman Diagram Showing Effect of Range of Stress Upon Endurance Limit.

Fig. 6 shows the curve for a mean tensile stress of 20,000 psi. with an endurance limit of 51,000 psi.

A modified Goodman diagram is shown in Fig. 7 of this report, in which ordinates to the upper line represent the maximum tensile stresses at the endurance limit, ordinates to the middle line represent the mean stresses, and ordinates to the lower line represent the maximum compressive stresses at the endurance limit for various ranges of stress tested. As indicated by the diagram, the endurance limits increase very nearly as a linear function of the mean stresses, both in the tensile range and in the compressive range. However, due to the greater slope of the lower line of the diagram, increases in endurance limit for the compressive range are larger than for the tensile range. Another viewpoint is that as the mean stress is increased in the *tensile* range, the maximum value of alternating stress which can be superimposed on the mean stress without causing fatigue failure *decreases,* while in the *compressive* range, the maximum value of alternating stress that can be superimposed on the mean stress *increases.*

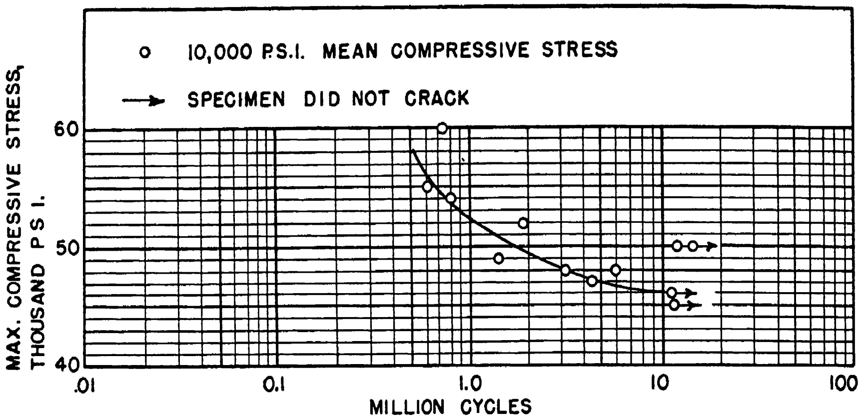


Fig. 4.—S-N Diagram for Fatigue Tests of Rail Webs.

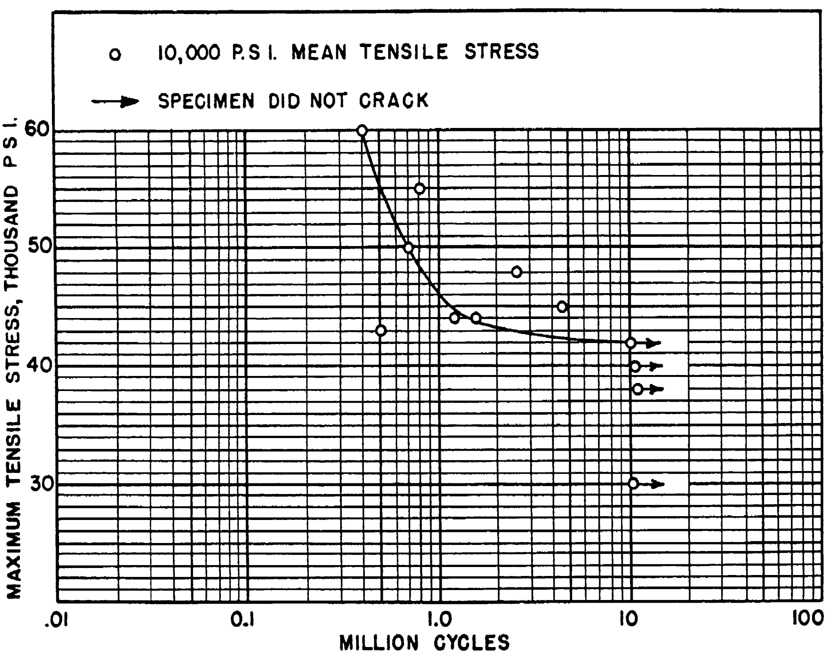


Fig. 5.—S-N Diagram for Fatigue Tests of Rail Webs.

Series I.—Continuous flow of tap water instead of a rate of 10 drops per min.

Series II.—Tap water mixed with sufficient H_2SO_4 to give a pH of 5.4 (3.4 cc H_2SO_4 per 5 gal. water). Rate—10 drops per min.

Series III.—Distilled water with NaCl added to make 4 parts per million. (125 mg. NaCl per 5 gal. water). Rate—10 drops per min.

Series IV.—Distilled water with chlorides and sulfates added to duplicate the Altoona water analysis and to get pH of 5.4 (H_2SO_4 added to get pH of 5.4) (135 mg. NaCl per 5 gal. water). Rate—10 drops per min.

Specimens were run under completely reversed stress and the speed of the machines was set to allow the specimens to run for 10 days before failure. The results were as follows:

Series	*Stress psi.*	*No. of Cycles for Failure*	
I	30,000	11,050,000—No crack	
I	30,000	10,160,500—No crack	
II	30,000	850,000	pH values 5.4
II	28,000	1,100,000	
II	26,000	1,500,000	
III	30,000	3,500,000	6.6 to 7.0
III	28,000	2,700,000	
IV	30,000	1,500,000	5.4
IV	28,000	1,300,000	

Since in these experimental tests, the specimens of Series II showed the most marked reduction in fatigue life, and since it was thought that a corroding agent such as was used for these tests of Series II would more nearly approach the corrosive conditions encountered in service, the tap water mixed with sufficient H_2SO_4 to give a pH value of 5.4 was selected as a corroding agent for further tests.

However, since it was definitely established that corrosion reduces the endurance limit, and that large variations in fatigue life could be obtained by varying the acidity or corrosiveness of the water; (that is, corrosion-fatigue failures can be obtained in the laboratory which correspond to failures in service) Subcommittee 11 decided against the feasibility of making a long series of corrosion-fatigue tests. It was the opinion of the committee that the problem resolves itself into one of preventing corrosion, as it is not feasible to redesign the rail within the corrosion-fatigue limits of rail steel.

The committee recommended that corrosion-fatigue tests be made under the following three ranges of stress, considered representative of stress conditions encountered in service:

1. Completely reversed stress.
2. Zero to maximum tensile stress.
3. Maximum compressive stress to a tensile stress 15 percent as great.

These tests are now in progress.

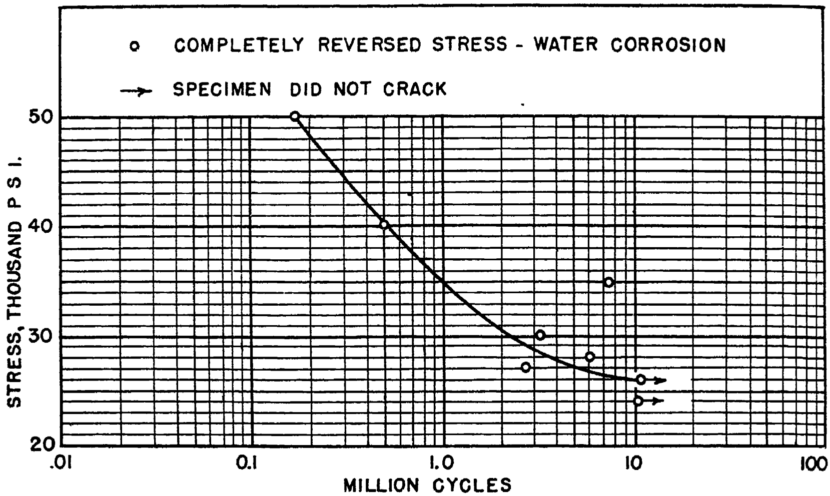


Fig. 8.—S–N Diagram for Corrosion-Fatigue Tests.

Fig. 8 shows the S–N diagram for specimens under completely reversed stress, with tap water corrosion and the machines running 10 min. of each hour for the first week each specimen was under test. By comparing the lower curve of Fig. 3 with the curve of Fig. 7, it may be seen that the corrosion lowered the endurance limit from 33,000 psi. to 26,000 psi. at 10 million cycles.

A few tests were made in which the specimens were given a "preconditioning" treatment by subjecting them to a large number of cycles of low stress under tap water corrosion, after which they were removed, cleaned and tested in the regular manner. These specimens showed no appreciable reduction in fatigue life compard to uncorroded specimens.

Laboratory tests thus far, under tap water corrosion, have not revealed as great a reduction in fatigue life of rail webs as service failures indicate. Corrosion-fatigue tests, using a continuous flow of tap water, which have been conducted in Altoona by Chairman Code, indicated a considerably lower fatigue life for rail webs than tests at the University of Illinois, and led to an investigation of the corrosive properties of the two types of water used.

A comparison of the analysis of the two types of water was made, which indicated the Altoona water was more corrosive than the University of Illinois water. The water analyses are as follows:

Part per Million	*Altoona*	*University of Illinois*
Total dissolved solids	105	340
Chloride, Cl	4.3	7.0
Acidity as SO_3	4.0	0
Bicarbonates	0	330
Oxygen (dissolved)	11.0	3 to 4
pH value	5.4 (Acid)	7.4 (Basic)

In order to obtain more severe corrosion on the specimens, four experimental tests were made, using the following corroding agents:

Report of Committee 5—Track

E. W. CARUTHERS, *Chairman,*
L. L. ADAMS
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M. F. AKERS
C. A. ANDERSON
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M. C. BITNER
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O. C. REHFUSS
M. K. RUPPERT
R. D. SIMPSON
G. J. SLIBECK
R. C. SLOCOMB
R. R. SMITH
C. R. STRATTMAN
TROY WEST
M. J. ZEEMAN

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Fastenings for continuous welded rail, collaborating with Committee 4.

   No report.

3. Track tools, collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR.

   Progress report, offering revised plans as recommended practice .... page 65(

4. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.

   Progress report, offering revised and new plans and specifications as recommended practice .... page 65.

   Appendix 4-a—Service tests on crossings .... page 65

5. Prevention of damage resulting from brine drippings on track and structures, collaborating with Committee 15, and Mechanical Division, AAR.

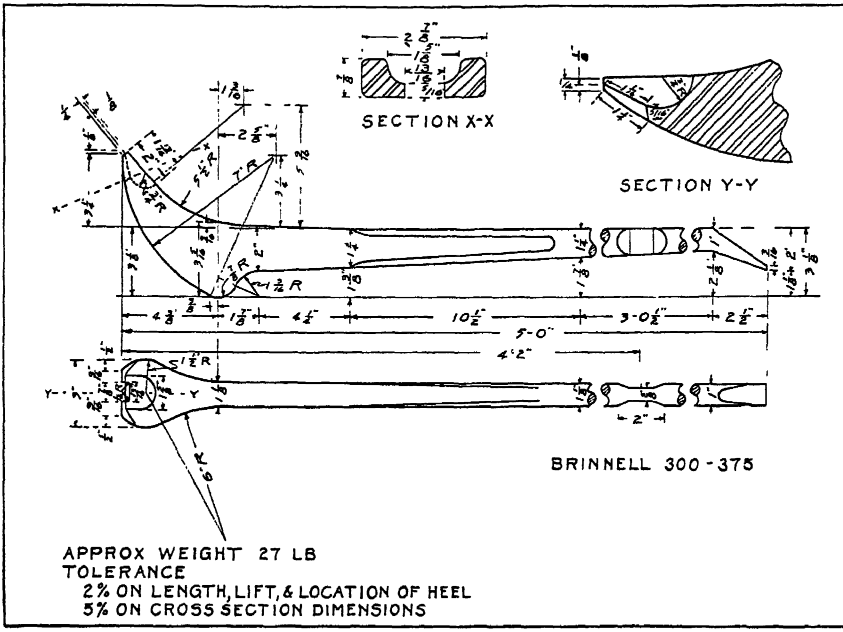
   Progress report .... page 66

6. Design of tie plates, collaborating with Committees 3 and 4.

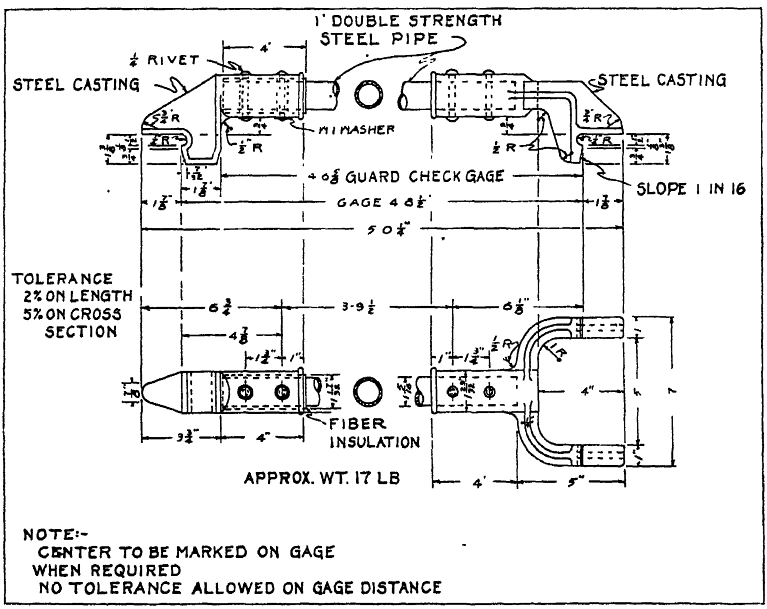
   Report on special design of tie plate for curves .... page 6(

   Report on tie plate service test measurements .... page 6?

Bulletin 486, February 1950.



Plan 11-50.—AREA Claw Bar.



Plan 20-50—Track Gage—Pipe Center.

THE COMMITTEE ON TRACK,
E. W. CARUTHERS, *Chairman.*

Report on Assignment 3

Track Tools

Collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR

C. E. R. Haight (chairman, subcommittee), F. J. Bishop, J. A. Blalock, H. J. Bogardus, A. E. Botts, M. D. Carothers, E. W. Caruthers, W. E. Cornell, L. W. Deslauriers, T. R. Klingel, E. E. Martin, S. H. Poore, R. C. Slocomb, Troy West.

In its report last year your committee submitted a revised design for the Claw Bar Plan 11–49, which was adopted. During the past year developments in manufacturing technique have permitted improvements of the design. These improvements consist of sloping the end of the spike slot backward at the bottom so that this portion of the claw bar does not bear against the back of the spike until the spike is practically withdrawn, permitting a firmer grip of the claw on the spike head and straighter drawing of the spike. It has also been possible to provide, near the pinch end of the bar, a deeper safety depression, making this feature more effective.

Th track gage plans, No. 20 for the pipe center gage and No. 20–A for the wood center gage, have been revised to provide a recess in the gage face at both ends of the tool to permit greater use of the tool where both rails are lipped. At the same time Plan 20–A for the wood center track gage was revised to provide greater underclearance of the handle. This revision was made in 1945 on the pipe center gage and permits greater use of the tool where portions of the track structure, such as guard rails, may be slightly above the top of the rail.

It is recommended that Plans 11–50, 20–50 and 20–A–50, containing revisions described above, be adopted and printed in the Manual as recommended practice.

Plan 710–50 Bolted Rail Crossings, Angles 14 deg. 15 min. to 80 deg. 10 min. inclusive.
" 768–50 Manganese Steel Insert Crossing Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive, for Rails Less than 6 in. in Height.
" 769–50 Manganese Steel Insert Crossings Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive, for Rails 6 in. and More in Height.
" 775–50 Solid Manganese Steel Frogs and Interior Rolled Closure Rails Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive, Single Rail Construction.
" 820–50 Graph Showing Limitations for the Use of Crossings with Rigid Center Frogs.

In view of the issuance of the plans listed above your committee recommends withdrawal of the following plans from the Portfolio of Trackwork Plans.

Plan 401–41 No. 10 Spring Rail Frog.
" 405–41 No. 10 Spring Rail Frog, Short Spring Rail Type.
" 407–42 No. 9, No. 11 and No. 12 Spring Rail Frogs.
" 408–42 No. 9, No. 11 and No. 12 Spring Rail Frogs, Short Spring Rail Type.
" 710–46 Bolted Rail Crossings Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive
" 768–46 Manganese Steel Insert Crossings Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive.
" 775–46 Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles 14 deg. 15 min. to 8 deg. 10 min., Inclusive, Single Rail Construction.
" 820–46 Graph Showing Limitations for the Use of Crossings with Rigid Center Frogs, Angles up to 15 deg. 30 min., Inclusive.

Your committee also recommends revision of Plan 700–41 Crossing Designs and Recommended Practices. In paragraph 3 Movable Point Crossings change the angle stated as 15 deg. 30 min. to read 14 deg. 15 min.

The Standardization Committee of the Manganese Track Society collaborated with your committee in the preparation of the new plans and the recommendations offered.

Your committee presents as information reports prepared by the research staff of the Engineering Division, AAR on service tests of solid manganese crossing frogs at McCook, Ill., service tests of manganese insert and solid manganese crossings supported on structural steel substructure and longitudinal timbers, new installation of a solid manganese crossing on a structural steel T-beam substructure of revised design and crossing frog bolt tension tests.

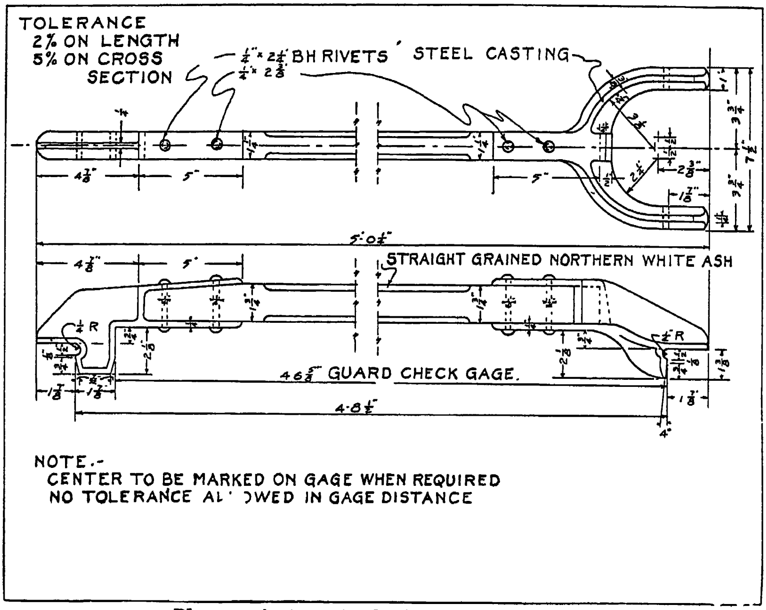
Appendix 4–a

Service Tests on Crossings

This is a progress report presented as information.

Solid Manganese Crossing Frogs at McCook, Ill.

This subject was last reported in the Proceedings, Vol. 50, 1949, page 572, in which the summary of the service test results, correlated with the dynamic stress measurements in the five designs of castings indicated the need for further investigation directed toward improvement of the design or material to minimize the occurrence of flangeway cracks.



Plan 20-A-50.—Track Gage—Wood Center.

Report on Assignment 4

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section, AAR

A. B. Hillman (chairman, subcommittee), L. L. Adams, J. C. Aker, C. A. Anderson, T. H. Beebe, F. J. Bishop, J. A. Blalock, A. E. Botts, C. W. Breed, H. F. Busch, E. W. Caruthers, W. E. Cornell, E. D. Cowlin, L. W. Deslauriers, J. W. Fulmer, P. X. Geary, W. E. Griffiths, A. F. Huber, W. G. Hulbert, C. T. Jackson, C. H. Johnson, T. R. Klingel, F. H. Masters, R. E. Miller, G. A. Peabody, S. H. Poore, J. A. Reed, O. C. Rehfuss, R. D. Simpson, G. J. Slibeck, R. C. Slocomb, C. R. Strattman, M. J. Zeeman.

Your committee has prepared revised plans of spring frogs to improve the vertical stability of the spring wing rail and has also prepared revised plans of crossings within the range of angles from 14 deg. 15 min. to 8 deg. 10 min. to provide better guarding for the center frogs. The proposed designs of manganese steel castings as shown on Plans 768–50 and 769–50 are consistent with the design shown on Plans 751–47 and 750–47, respectively.

Your committee offers the plans listed below with the recommendation that they be adopted as recommended practice for publication in the Portfolio of Trackwork Plans.

Plan 401–50 No. 10 Spring Rail Frog.

" 405–50 No. 10 Spring Rail Frog, Short Spring Rail Type.

" 407–50 No. 9, No. 11 and No. 12 Spring Rail Frogs.

" 408–50 No. 9, No. 11 and No. 12 Spring Rail Frogs, Short Spring Rail Type.

Fig. 2.—Revised Taylor-Wharton Casting After Three Years of Service.

Fig. 3.—Carnegie-Illinois Casting After Two Years of Service.

Installation of Shot Peened Casting

Fatigue tests of manganese steel (Vol. 50, 1949, page 579) have indicated that the endurance limit stress of shot peened specimens was appreciably higher than that for the as cast or ground specimens. An arrangement was made to obtain a new depth hardened casting of the same Morden–Ramapo design previously tested to explore the possibility of eliminating or delaying flangeway cracks by shot peening the flangeways. The casting was shot peened by the American Wheelabrator & Equipment Corp. in its testing laboratory at Mishawaka, Ind. Two passes under the shot ejector were directed to each fillet in both flangeways, with the casting titled about 25-deg. from its normal position to obtain maximum intensity of peening in the flangeway fillets. A part of the running surface was shot peened as well as the upper part of the casting at the guard rail junction. The casting was installed in the test corner of the crossing between the eastward mains of the Atchison, Topeka & Santa Fe Railway and the Baltimore & Ohio Chicago Terminal Railroad, April 25, 1949. A photograph of this casting was taken July 28, 1949, and in Fig. 1 it will be observed that the depth hardened running surfaces had not yet worn down to fit the average wheel tread. There was no evidence of any cracks in the casting.

Inspection in 1949

An inspection made July 28, 1949 revealed that the revised Taylor–Wharton and the Carnegie–Illinois castings were still in use and the other three test castings were no longer in service.

The revised Taylor–Wharton casting shown in Fig. 2 was in the position opposite to the test corner and had a small crack at both the Santa Fe and B. & O. wings and

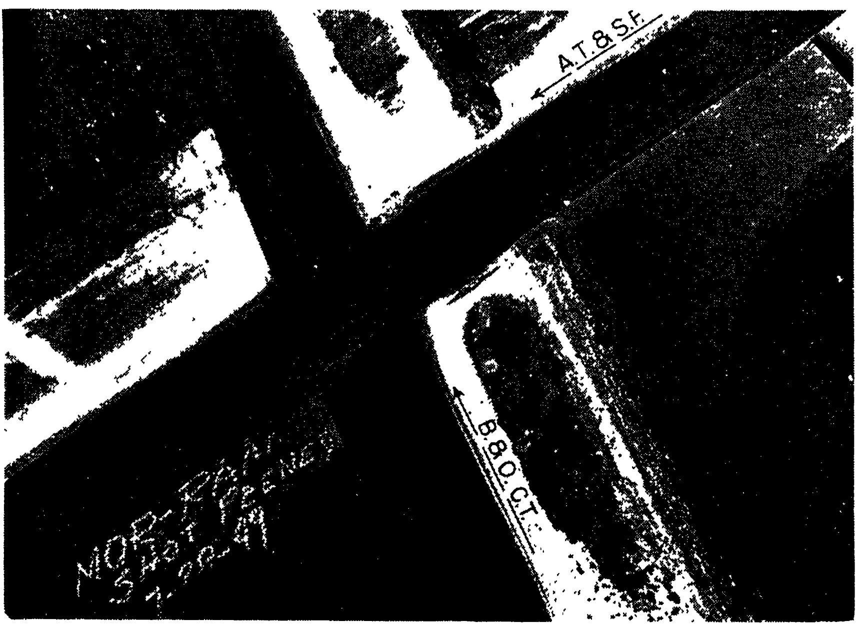


Fig. 1.—Morden–Ramapo Shot Peened Casting After Three Months of Service.

Manganese Insert and Solid Manganese Crossings Supported on Structural Steel Substructure and Longitudinal Timbers

The four crossings involved are in the double-track main lines of the Indiana Harbor Belt Railroad and the Chicago & Western Indiana Railroad near 55th Street and Cicero Avenue, Chicago, Ill., and were installed October 14, 1946. One each of the solid manganese and insert type crossings is supported on steel T-beams and the other two crossings have longitudinal bolted timbers.

Inspection in 1949

Generally, the crossings on steel supports and asphaltic concrete ballast are tamped up twice a year.

An inspection was made of the crossings May 10, 1949, and Fig. 4 is presented to show the flangeway cracks. The length of the cracks is shown to the same scale as used for the flangeway width. Since last year's report the flangeway cracks in both of the solid manganese crossings had extended appreciably. There was no change in the cracks of the insert type crossing A, supported on the T-beams and only a slight change at the northeast corner of crossing C. The relative extent of the cracks was about the same, regardless of kind of support, for the two types of crossings. On the crossings having the T-beam support one clip bolt and four clips were broken. All crossings were out of line slightly in the east and west direction and the movement had been with the traffic on the north and south tracks. The crossings in other respects were in good condition except for some batter on the castings. A view of the two crossings supported on the steel substructure is shown in Fig. 5.

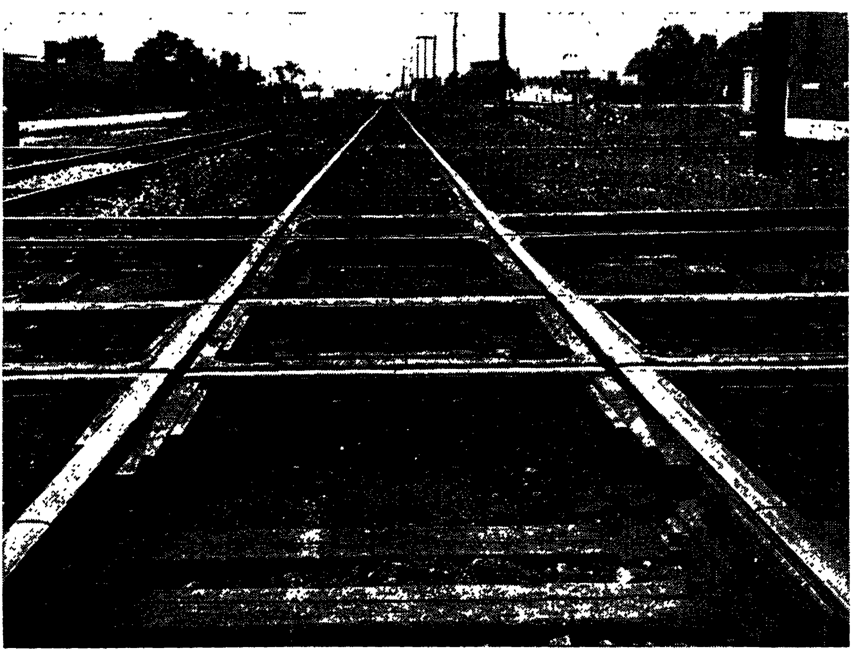


Fig. 5.—Solid Manganese and Reversible Manganese Insert Crossings Supported by Steel Substructure of Original Design.

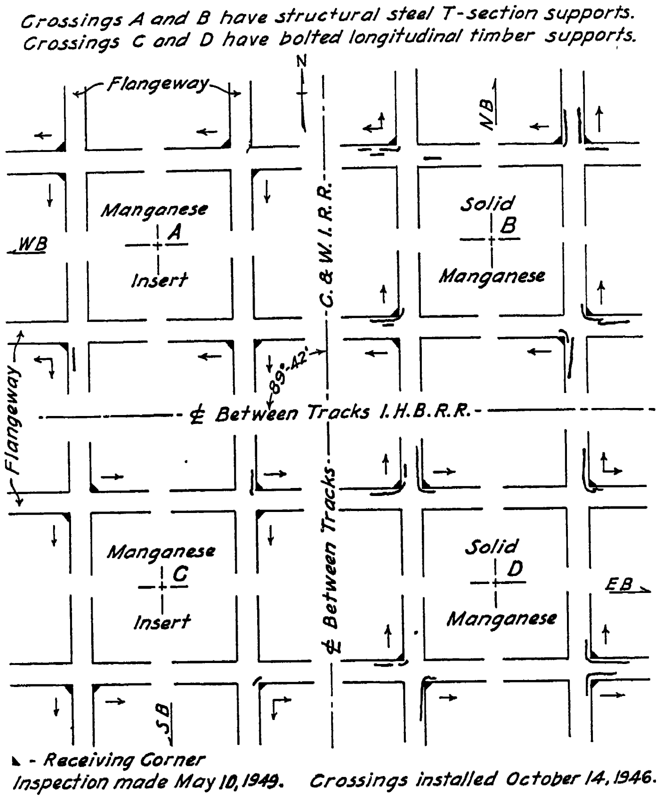


Fig. 4.—Flangeway Cracks in Four Crossings of the C. & W. I. R. R. and I. H. B. R. R., near 55th Street and Cicero Avenue, Chicago, Ill.

the flangeway was badly cracked around the Santa Fe receiving—B. & O. leaving corner and adjacent to the B. & O. receiving corner. This casting has been in service three years.

The Carnegie–Illinois castings shown in Fig. 3 after two years' service in the same corner as last reported had a small crack in the B. & O. wing and a large crack across the Santa Fe wing. A long crack also extended in the flangeway around the B. & O. and Santa Fe common receiving corner.

The original Taylor–Wharton design had 1½ years' service before it was removed December 12, 1948 because it was bent in a derailment. This casting was examined after removal from the track and found to have cracks at both wings, a long crack in the Santa Fe flangeway, a short one in the B. & O. flangeway at the B. & O. receiving corner and also four small cracks extending from two of the openings in the base.

The Morden–Ramapo casting was in service on April 25, 1949 but was out of the track July 28, 1949 and had a total service of 4½ years. It was badly cracked in the flangeways, but no cracks had formed at the guard-rail junctions.

After eight months' traffic the Bethlehem design was retired from service. It had developed rather long flangeway cracks at both of the receiving corners, and shorter cracks at the guard rail junctions and in the grillage supporting flangeway floors.

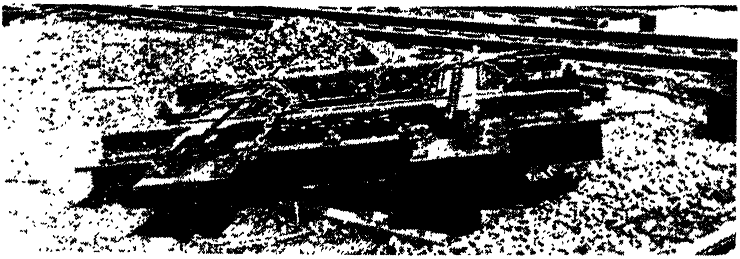


Fig. 6.—New Design of Steel Substructure and Crossing Assembled for Setting in Place.

Fig. 7.—New Crossing and Steel Support During Installation.

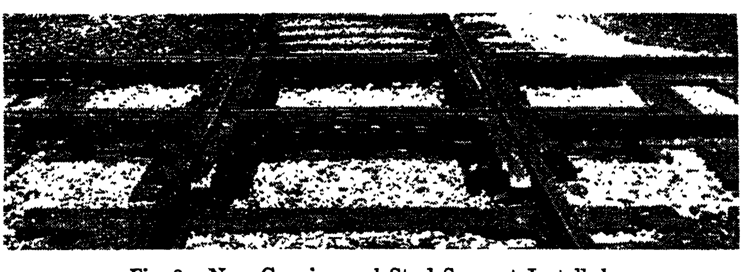


Fig. 8.—New Crossing and Steel Support Installed.

New Installation of a Solid Manganese Crossing on a Structural Steel T-Beam Substructure of Revised Design

Foreword

From stress measurements made in the structural steel T-beam supports of the crossings installed in 1946 on asphaltic concrete ballast, it was developed that the welds at the intersection of the stem of the T-sections had failed and this was principally attributed to the failure of the asphalt in the ballast to take final set and give the substructure proper support. The results of the service tests, so far, indicate that this weld failure had nullified the benefits expected from the installation. In 1948 arrangements were made with the Belt Railway Company of Chicago to install another steel substructure of improved design in connection with the renewal of two crossings in its tracks about 40 ft. south of the 1946 installation near 55th Street and Cicero Avenue, Chicago, Ill. This was a cooperative arrangement between the Belt Railway Company and the Association of American Railroads, the latter paying the cost of providing the steel substructure and the railway assuming the cost of placing.

Type of Construction

Both the old and new designs of steel supports had 1-in. by 20-in. steel base plates for flanges of the T-beam sections. The web or stem of the T-beams was made thicker by using 1½-in. by 10-in. plates instead of the original 1-in. by 10-in. Fifty-six 8-in. by 8-in. triangular gusset plates or brackets, ¾-in. thick, were used instead of 48. The top plates were welded together with a closed double-bevel butt joint instead of a single bevel. In both designs the stem sections had welded T-joints at the junctions. The new substructure had a double bevel on the ends of plates abutting the through plates and the welding extended across the entire thickness of the 1½-in. plate as well as the length. The old design had no bevelling and the beads were laid in the square corners of the T-joint. The two solid manganese crossings, having an angle of 89-deg. 42 min., were of AREA design, Plan 771–40, with a 6-in. height. The clips and 1-in. clip bolts were of the same design as previously used. The clip bolts had double-coil spring washers and Security nuts. The steel support and crossing frog were manufactured by the Pettibone Mulliken Corporation, Chicago.

Installation of Crossings

The two crossings were placed by the Belt Railway forces May 6, 1949 in the intersections of the Elsdon Branch track with the same double-track north and south main lines in which the original steel supports were laid in 1946. The crossing with the improved T-beam substructure is in the northbound main and the other solid manganese crossing with cross timber support is in the southbound track. Both crossings were surfaced on crushed stone having a maximum size of 1½ in. No asphalt was used for either installation, although this may be added later if developments make it appear desirable. Three views of the crossing with the steel support are presented in Figs. 6, 7 and 8.

Crossing Frog Bolt Tension Tests

Foreword

The object of these tests is to determine the reactive characteristics required of spring washers for more economical and satisfactory maintenance of adequate bolt tension in crossing and turnout frog bolts.

Report on Assignment 5

Prevention of Damage Resulting from Brine Drippings on Track and Structures

Collaborating with Committee 15 and Mechanical Division of the AAR

W. E. Cornell (chairman, subcommittee), F. J. Bishop, M. C. Bitner, Blair Blowers, E. W. Caruthers, P. H. Croft, M. H. Dick, C. T. Jackson, H. F. Kimball, E. R. Murphy, C. E. Peterson, C. E. Price.

The last committee report on this subject was given in the Proceedings, Vol. 45, 1944, page 339. As explained in previous reports, extensive laboratory tests were carried out, adding various types of inhibitors to brine solutions to determine their comparative effectiveness in minimizing corrosion of steel. These tests in the laboratory indicated that the use of sodium dichromate neutralized with soda ash would be very effective in protecting the track and bridge structures from corrosion due to brine drippings from refrigerator cars.

A test run was then made with a refrigerator car from Los Angeles to Chicago, the dichromate inhibitor being added each time the car was iced. Samples were collected of the brine drippings from point to point and analyzed to determine the degree of uniformity of inhibitor content and the pH or relative acidity of the resulting solution. These tests indicated that although there was some concentration of inhibitor above the desired amount immediately after icing, generally speaking the inhibitor content in the brine drippings over the entire trip was such as to give good protection.

Track Tests Confirm Laboratory Tests

This test was then followed with a test in track in which a number of tie plates, after being carefully weighed, were sprayed by hand each day by the section forces with a brine solution, while others were sprayed with brine solution containing the inhibitor. It was found in this track test that the inhibitor very effectively eliminated corrosion and, in fact, the amount of corrosion of the tie plates sprayed with the brine and inhibitor was even less than of plates exposed only to the atmosphere.

Arrangements were then made to make a test of the inhibitor in a refrigerator car in shuttle service between Cincinnati, Ohio, and the East, but due to the toxicity of the sodium dichromate the shippers objected to its use because of the possible contamination of the lading. The subject was then referred to the Medical Section of the AAR, which offered the opinion that it would be necessary to add the dichromate in such manner as to avoid any possible contamination of the lading, although no objections were made to the discharge of the dichromate on the track and bridge structures from the standpoint of toxic effects. Evidently, the only way to meet this condition satisfactorily was to devise a filter which could be attached to each discharge spout of the refrigerator cars, permitting the brine to pass through it and thus receive the desired concentration of dichromate.

Study Conducted at Armour Research Foundation

During the past several years it has not been possible to continue work on this investigation, but provision was made in the research program for 1949 for the development of a suitable filter for this purpose. Arrangements were made with Armour Research Foundation to carry on this investigation, and to give consideration also to the use of recently developed nontoxic inhibitors which might be equally as satisfactory as the

Last year's report gave information on the procedure to be used in making these investigations and included description of tests that had been started on two sets of crossings in Chicago where the traffic involved was principally slow speed freight movements and slow speed passenger trains at one of the locations. Some progress has been made in conducting these tests on three types of crossings, but a longer service period is needed to develop sufficient data for an informative and comprehensive progress report.

Main Line Crossing Test

The Pennsylvania Railroad very kindly volunteered to have a test of a crossing made on its double-track line at Warsaw, Ind., about 110 miles east of Chicago, Ill. That is an excellent location where high speed operation prevails. Passenger trains reach a maximum speed of 80 mph. and freight trains about 65 mph.

The crossing selected for these tests is located in the eastward main track and a branch line of the New York Central System which has a light traffic density and slow speed operation at the crossing. Most of the passenger trains and some of the freight trains are hauled by diesels. Steam power operating over the crossing includes heavy locomotives of the duplex type having four cylinders, divided-drive and rigid frame.

The crossing frog is of the three-rail bolted cut-rail type similar to AREA design 701–40, modified to conform with the Pennsylvania's specifications, and made of 131 RE rail. All rails and flangeway fillers were heat treated. The crossing has an angle of 81 deg. 43 min. and is supported on longitudinal timbers under the Pennsylvania rails, and stone ballast. It was built to ⅛ in. tight gage on the Pennsylvania side and to standard gage on the New York Central side. The main bolts are 1⅜ in. by 14 in. and have a drive fit. The crossing was placed in the track in May 1948 and is in good condition.

In each corner of the crossing a different weight of spring washer for the 12 main bolts is being tested. These will include the P.R.R. standard specification, the Hubbard experimental spring washer, a laminated type D–5 compression washer and an extra heavy coil spring washer developed by the Reliance Division of the Eaton Manufacturing Company. The foregoing washers have, respectively, the following reactive pressures at a release of 0.030 in. from a 40,000 lb. load: 3000, 10,000, 20,000 and 15,000 lb. A supplemental test is also being made with special lock nuts such as Elastic Stop nuts, Security nuts and the MacLean–Fogg Unitary nut No. 3. In a corner with 12 main bolts, 6 have the special lock nut and the others have ASA regular square nuts of high strength and class 2 fit. All of the lock nuts are made of low carbon.

The first cycle of this test was started July 12, 1949 with approximately 40,000 lb. bolt tension which requires two men on the standard frog wrench. Later, tests will be made with a lower bolt tension which will represent the practice of tightening bolts with only one man on the wrench.

Bolt tension tests will also be made at Warsaw, Ind. on a No. 15 railbound manganese frog when the special length bolts become available.

Acknowledgement

The Association is indebted to the Pennsylvania, the Indiana Harbor Belt, the Belt Railway Company of Chicago and the Baltimore & Ohio Chicago Terminal for their fine cooperation and assistance in making these tests, and also extends its appreciation to the manufacturers for their valuable assistance in conducting these investigations.

reports. Samples consisted of small round disks of steel corresponding to that used in tie plates, spikes and bridge structures, and a specified amount of the brine solution was applied to the surface of the disk twice daily for the test period. The tests with the sodium dichromate were repeated to give a correlation with the previous tests.

Observations

The following observations were made from the first month's results:

1. Sodium dichromate plus soda ash eliminated over 90 percent of the corrosion and rendered the brine less corrosive than distilled water (or rainwater). This confirms conclusions reached in previous tests.

2. Sodium chromate, as predicted from its chemical composition, gave results entirely equivalent to dichromate plus soda ash. This permits the addition of one ingredient instead of two.

3. Unsatisfactory inhibition was obtained with Banox 1 (eliminated about 70 percent of corrosion), Nalco 818C (eliminated about 75 percent), and basic iron phosphate (eliminated only 18 percent).

4. Sodium nitrite was found by the Food and Drug Administration to be toxic. It also required excessive amounts for effectiveness in our tests.

5. Sodium polyphos (corresponding to sodium hexametaphosphate in composition) reduced corrosion by an average of 85 percent and was equivalent to the chromate over much of the concentration range.

6. Results with disodium phosphate were inconclusive and at least one month's further testing will be required. It appears possible that small critical amounts may be effective, making possible considerable savings in inhibitor cost.

Conclusion

These tests may be summarized by saying that sodium polyphos, and possibly disodium phosphate, give promise as nontoxic brine corrosion inhibitors. As such they could be added directly to the ice or salt in the bunker. Sodium chromate, as a single ingredient, is equivalent to sodium dichromate plus soda ash, but is equally toxic and must be added outside the car.

It is evident from the investigation so far that the cost of adding the inhibitor is going to be an important consideration in the economy of the procedure. Accordingly, Armour Research Foundation is preparing a report of the work completed to date, together with rather comprehensive estimates of the cost of brine corrosion protection using the various types of inhibitors, and it is believed that this economic study will rather clearly define the methods that appear to have possibility of economical use and on which further research and investigation will be required to develop them to the point of making definite recommendations for their use and the method of application.

dichromate and yet be applied directly with the salt while icing the car. This work has been progressed at the Foundation during the year, and there have been several joint meetings of this subcommittee with representatives from the Mechanical Division of the AAR to discuss the progress and plan for the research work being conducted at the Foundation.

Search Made for Suitable Filter

Efforts were first concentrated on the development of a suitable type of filter for adding the inhibitor. It was recognized that the device for external application of the dichromate would have to be capable of adding the inhibitor to the brine with wide variation in the rate of brine flow, temperature, and salinity, and still give reasonably uniform concentration. The device would necessarily have to be rugged, compact, freeze-proof, clog free, and easily charged and discharged.

A solid pressed pellet was felt to be the most compact form in which the inhibitor could be introduced and was, therefore, investigated first. Using pressures of 4000 psi., strong pellets of sodium dichromate, soda ash and sodium chromate were successfully molded without the use of any binder. These pellets, however, melted in an irregular way, leaving crevices and pores, and wore away from the path of the effluent so that the inhibitor concentration became very low toward the end of the life of the pellet. This objection applied whether the effluent passed under, over or through the pellet.

Try Bag of Inhibitor Crystals

The next method of addition tried was the use of a bag containing crystals of the inhibitor. When the bag was placed directly beneath the overflow spout so that the water passed in at the top and out at the bottom, an inhibitor content of about 100 times the desired amount was obtained at the beginning. This content decreased as the crystals dissolved. These difficulties were partly obviated by hanging the bag so that the bottom rested against the trough through which the effluent passed, providing a constant area of contact between solid and liquid and allowing the crystals to fall from the top of the bag to replace those which dissolved at the bottom. Since the rate of dissolving was still high and was affected by the rate of brine flow, a reservoir was placed in the trough, a siphon arrangement permitted the reservoir to trip only after it was full, cascading the brine down the trough at a rate which was independent of the rapidity with which the ice melted. However, this mechanism appears to be vulnerable to freeze-ups and clogging and, therefore, not desirable from the maintenance standpoint. Thus, it is evident that an entirely satisfactory filter method of adding the inhibitor has not yet been developed, and further work will need to be done if it is decided that this method offers promise of practical development.

Study Nontoxic Inhibitors

The laboratory tests conducted on nontoxic inhibitors give some promise that it may be possible to secure the desired corrosion protection by using a nontoxic inhibitor, adding this directly with the salt, which will undoubtedly be the least expensive and most satisfactory method of making the addition. Consideration is also being given to the possibility of adding the inhibitor to the water before it is frozen to form the ice which, if practical, would give the most uniform rate of inhibitor application that could be obtained.

Tests were carried out in the laboratory to evaluate the corrosion protection of other types of inhibitors, in a manner similar to that reported in previous committee

tie plate length represents a diagram of the damaging pressures on the tie and the centroid of the trapezoid locates the resultant of the pressure. If a tie plate has the eccentricity required to make its mid-length coincide with the centroid of pressure, then the penetration at the plate ends should be equalized and canting of the rail from that cause should be practically eliminated. In this report the eccentricity of a tie plate load is the distance from its centroid to the centerline of the rail base. Tie plate eccentricity is the distance from the centerline of the rail base to the mid-length of the plate.

Tangent Track

On several railroads the penetration measurements in tangent track have shown that for tie plates with a 1:40 cant, the centroid of tie plate loads is located about 0.2 in. outward from the centerline of the rail base. Tie plates having ¼-in. eccentricity and 1:40 cant should maintain good gage on tangent track with little or no widening caused by unequal penetration, and those with ⅜-in. eccentricity will tighten the gage slightly, but experience has shown that this is not objectionable. Most of the existing AREA tie plate designs are excellent for tangent track as far as their eccentricity is concerned, and it is seldom necessary to regage tangent track because of unequal plate cutting.

Curved Track

On curves of 3 deg. and sharper where the predominant speed of operation is somewhat below equilibrium speed, tie plate penetration at the field end of the plates under the inner rail is much larger than at the gage end. This causes the rail to cant outward and progressively widen the track gage, and also increases the lateral flow of the metal in the rail head. To correct this condition it is necessary to re-adze and set up the low rail to the proper cant and gage, thereby ultimately spike killing the ties and promoting decay by frequent re-adzing. Preliminary measurements showed that the eccentricity of tie plate loads on both rails of most of the curves was much greater than the tie plate eccentricity which places the centroid outside of the mid-length of the plates.

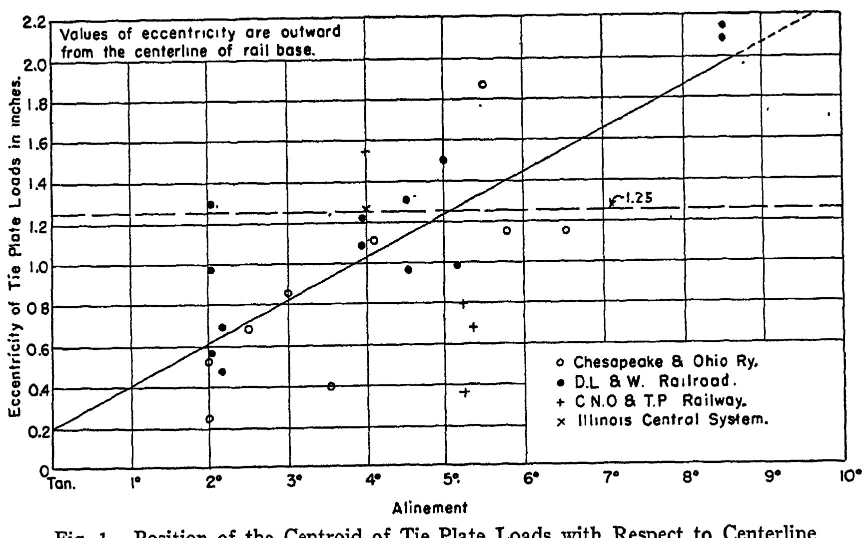


Fig. 1.—Position of the Centroid of Tie Plate Loads with Respect to Centerline of Rail Base, for Inner Rail Only.

Report on Assignment 6

Design of Tie Plates

Collaborating with Committees 3 and 4

J. de N. Macomb (chairman, subcommittee), L. L. Adams, C. A. Anderson, F. J. Bishop, T. E. Bliss, Blair Blowers, A. E. Botts, C. W. Breed, M. D. Carothers, E. W. Caruthers, F. W. Creedle, R. A. Emerson, J. W. Fulmer, P. X. Geary, B. F. Handloser, J. P. Hiltz, C. T. Jackson, C. H. Johnson, E. E. Martin, J. A. Reed, R. D. Simpson, R. C. Slocomb, M. J. Zeeman.

This report, consisting of two parts, is submitted as information.

The first part resulted from the investigations being conducted by the AAR Engineering Division research staff for the subcommittee which have indicated the advantages of specially designed tie plates for use on curved track to reduce the maintenance costs of periodically re-adzing ties to restore gage and cant of rail. The following report gives the results of these investigations together with suggested designs of tie plates for use on curves of 3 deg. and over, for consideration by the Association.

The second part covers the service tests for purposes of tie plate design in 131 RE rail territory on the Cincinnati, New Orleans & Texas Pacific Railway, where seven patterns of tie plates have been under test since November 1944.

This investigation and report were made under the direct supervision of H. E. Durham, track engineer, research staff, and under the general direction of G. M. Magee, research engineer, AAR.

Special Design of Tie Plates for Curves

Introduction

In 1944 two service test installations of seven tie plate designs were placed in tangent and curved track. One of these tests is being conducted on tangent track and a 4-deg. curve on the Illinois Central Railroad near Curve and Henning, Tenn., and the other one involving a 6-deg. curve and tangent track is located on the C. N. O. & T. P. Ry. (Southern Railway System) near Chattanooga, Tenn. Stress measurements in the tie plates and rail were made at the two locations in 1945 and 1946. This work also included the measurement of the magnitude and eccentricity of tie plate loads on a 4-deg. curve and tangent track, with dynamometer tie plates. Tie plate penetration, track gage and tie plate bending measurements have been taken in alternate years and reported. In the service tests with new ties and tie plates the rate of mechanical wear of the ties has been quite small.

In order to expedite this investigation, many tie plate penetration data have been taken on several railroads during the last three years, first by temporarily removing the tie plates to observe the amount of plate cutting, and later by taking dial readings from the top of the plates to the original adzed surface of ties that had not been re-adzed. These data included older ties with more plate cutting than that of the service tests, and curvature from 2 deg. to 8 deg. 30 min. for a wide range of operating conditions.

Discussion of Test Data

Position of Centroid of Tie Plate Loads

It has been shown in the Proceedings, Vol. 50, 1949, pages 18–49, that the position of the centroid of the loads imposed on a tie plate may be determined from the amount of plate cutting at the ends by assuming that the trapezoidal recess in the tie along the

Penetration Measurements on Four Railroads

Extensive measurements were taken on the double-track lines of the Delaware, Lackawanna & Western Railroad, the Chesapeake & Ohio Railway and the Southern Railway System (C. N. O. & T. P. Ry.) in order to obtain information for a wide range of curvature and operating conditions. The field data were taken in the vicinity of Scranton, Pa. on the Lackawanna, where both steam and diesel power were operated, the largest steam locomotive being the 4–8–4 type. Measurements taken on the Southern extended from Cincinnati, Ohio, to Oakdale, Tenn., and over one-half of the traffic was hauled by diesels, the largest steam locomotive being a moderate size mountain type (4–8–2). Penetration data taken on the C. & O. included the line from Hinton, W. Va., westward for about 70 miles and part of the single-track James River line. All road power was steam and the largest was the Alleghany type (4–6–6–6) locomotive. Measurements on the Illinois Central were confined to the test curve near Curve, Tenn. These measurements, together with essential information on the operating characteristics of each location are presented in Table 1, the last three columns showing, respectively, the eccentricity of tie plate loads for the outer rail, the inner rail and the average of the two rails. These values have been plotted in Figs. 1, 2 and 3 for convenient analysis. In most instances where slow speed is involved the low rail cants outward more than the high rail and the inner rail presents the chief maintenance problem. In Fig. 1 for the inner rail of the curves, there is considerable scatter in the values. The scatter is less for the outer rail shown in Fig. 2 and only moderate in Fig. 3, which gives the mean values for both rails of each curve. In all three figures the values increase generally with the degree of curvature, and the ascending lines indicate the trend of the values from 0.2 in. (on the left for tangent track) to the two 8-deg. 30-min. curves. The values for each rail (Figs. 1 and 2) obviously reflect differences in operating conditions, except for the two 8-deg. 30-in. curves. For instance on curves of 6 deg. and under, if the speed is appreciably below that for equilibrium, the eccentricity of the tie plate load for the inner rail of a curve will be in the upper range while with all high speed operation the value will be in the lower range. The converse is true for the outer rail, but to a lesser extent. In the case of the average values for the two rails (Fig. 3) the plotted points follow the trend line reasonably well. For a given degree of curve there is a pronounced (although not uniform) tendency for the average values of the two rails to be fairly constant, regardless of the speed of operation in relation to the equilibrium speed.

Eccentricity of Tie Plate Loads vs. Predominant Speed in Relation to Equilibrium Speed

Observations on the various railroads as well as the measurements have shown that for curves of 6-deg. and under, the outward canting of the inner rail is influenced more by the predominant speed of the slow trains (usually freight trains) than by the degree of curvature. The inner rail of the 4-deg. test curve on the Illinois Central, where the tie plate design service tests are under way and the heavy tonnage freight operates at about 20 mph., has canted outward much more than on the 6-deg. tie plate test curve on the Southern, where practically all trains operate at or above balanced speed.

For the curves below 6 deg., shown in Table 1, an analysis was made of the tie plate load eccentricity for the inner rail and predominant speed of the freight trains expressed in inches of elevation below and above that for balanced speed of each curve. The values for the inner rail below balanced speed formed a rather definite pattern from 3 in. to 1 in. below balanced speed. Outside of that range there were too few values to

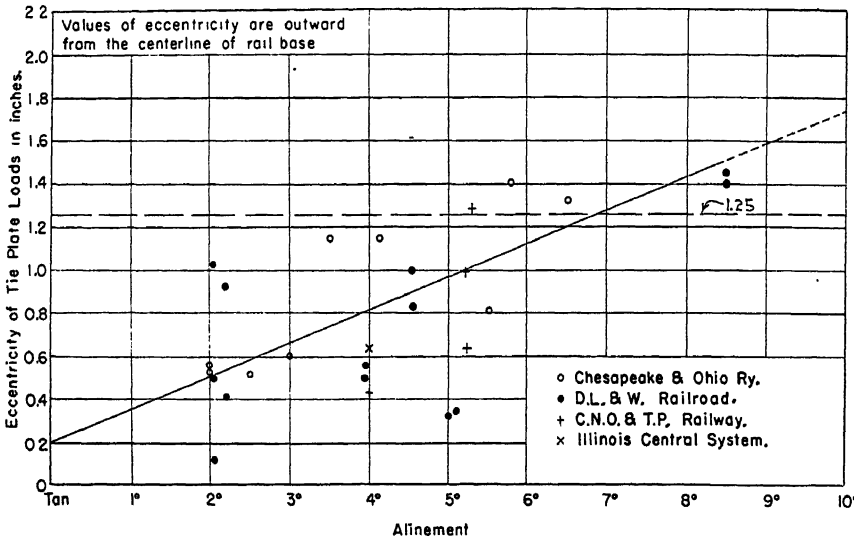


Fig. 2.—Position of the Centroid of Tie Plate Loads with Respect to Centerline of Rail Base, for Outer Rail Only.

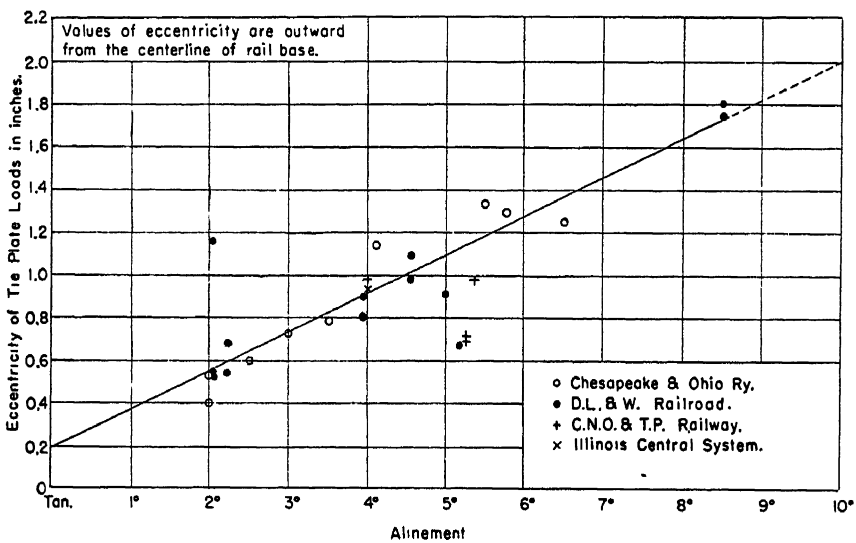


Fig. 3.—Position of the Centroid of Tie Plate Loads with Respect to Centerline of Rail Base, Average of Both Rails.

determine the trend, particularly above balanced speed. Values for the mean curve were approximately: 1½ in. tie plate load eccentricity at 3 in. below balanced speed; 1 in. eccentricity at 2 in. below balanced speed and ⅝ in. at 1 in. below equilibrium speed. These figures are not intended for the purpose of determining whether a special tie plate for a curve should be used, but they do emphasize that the eccentricity of the tie plate loads increases as the predominant speed of the greater portion of the tonnage drops below the equilibrium speed of a curve.

A similar analysis was made for the outer rail of the curves, but there was considerable scatter in the platted points. It is probable that trains operating at or above balanced speed have more influence on the tie plate load eccentricity in the outer rail than those operating below balanced speed.

Field data for curves sharper than 6 deg. included only one 6-deg. 30-min. and two 8-deg. 30-min. curves because of the scarcity of the sharper curves and also due to unsuitable conditions for these measurements brought about principally by recent readzing and regaging. However, it can be observed from Table 1 that a special tie plate with a large eccentricity would be quite beneficial for both rails of all three curves.

Selection of Tie Plate Design for Curves

It was shown in the Proceedings, Vol. 50, 1949, pages 18–39, that tie plate loads as well as wheel loads are quite large on curves, particularly on the low rail. These conditions impose damaging pressures on the ties. Bearing pressures on the wood are several times larger at the field end of the plate than at the gage end. Longer tie plates will reduce the average bearing pressures on the ties but will accomplish little in equalizing the pressures throughout the length of the plates, unless the design is such that the mid-length of plate is close to the centroid of pressure. From the data in Table 1 it is apparent that tie plates with an eccentricity much larger than that of the AREA double-shoulder designs will be required to bring about more nearly uniform pressure on the ties and to reduce the maximum damaging pressures effectively.

The scatter of the plotted points in Figs. 1 and 2 emphasizes the complexity of this problem. However, from a practical viewpoint, only one special tie plate for each rail base width should be considered. It is believed that the greatest mileage of curves needing a special tie plate, particularly for the inner rail, are those from 4-deg. to 6-deg., incl. Giving first consideration to the inner rail (Fig. 1), a tie plate design having an eccentricity of 1¼ in. seems to be the best compromise. The horizontal dashed line in Figs. 1 and 2 represent the 1¼ in. eccentricity. When a tie plate with this eccentricity is used on one rail of a curve where the eccentricity of the tie plate loads is ⅜ in. greater or less than 1¼ in., track gage variation because of unequal plate cutting should not exceed plus or minus ⅛ in. In Fig. 1 there are only three points above 1⅝ in. and none is in Fig. 2. The special tie plate will also be beneficial for these conditions but will not prevent the rail from canting outward to some extent.

The tie plate designs recommended for the 5½-in. and 6-in. rail bases, respectively, are presented in Figs. 4 and 5. A 15-in. plate is proposed for the 5½-in. rail base and one 16 in. long for the 6-in. rail base. These heavy tie plates seem justified for curves, where needed, particularly for the low rail where the dynamic wheel load on the rail is sometimes as high as the driving axle load. The 8-hole symmetrical punching in the 15-in. plate conforms to the current AREA plan for the 13-in. tie plate for the 5½-in. rail base, and the 16-in. plate for the 6-in. rail base has the same punching as the 14-in. AREA tie plate. For roads using those 13-in. and 14-in. tie plates, another tie boring template will not be required.

TABLE 1. TIE PLATE PENETRATION DATA AND CALCULATED POSITION OF THE CENTROID OF TIE PLATE LOADS FROM MEASUREMENTS TAKEN ON VARIOUS RAILROADS (1948-1949)

General Information							Speeds - mph.			Treated Oak Ties	Penetration of Tie Plate Ends in 0.01 in. (c)							Eccentricity of Tie Plate Loads - in. (d)		
					Rail (b)			Predominant			Outer Rail			Inner Rail						
Mile Post	Main Track	Grade % (a)	Alinement	Elev. in.	Wt. in lb.	Date	Authorized	Pass.	Frt.	Date	F.E.	G.E.	Avg.	F.E.	G.E.	Avg.	Avg. both Rails	Outer Rail	Inner Rail	Avg.
Delaware, Lackawanna & Western Railroad 7 1/2" x 12 13/16" D.S. Flat Bottom Tie Plate; 1:40 Cant, 3/8" Eccentricity																				
134.5	W.B.	+1.42	2°-02'	2	130	1934	50	35	15	1941	07	09	08	12	09	11	10	+0.11	+0.97	+0.54
134.5	W.B.	+1.42	2°-02'	2	130	1934	50	35	15	1933	22	12	17	23	09	16	17	+1.03	+1.30	+1.17
135.0	W.B.	+1.42	2°-12'	1 3/4	130	1934	50	35	15	1941	09	09	09	10	08	09	09	+0.41	+0.69	+0.55
135+	W.B.	+1.42	3°-55'	3	130	1934	40	35	15	1941	13	11	12	14	06	10	11	+0.56	+1.22	+0.89
92.3	W.B.	+1.33	5°-00'	4	130	1930	45	30	20	1942	17	18	17	26	08	17	17	+0.32	+1.50	+0.91
137.1	W.B.	+1.42	5°-09'	4	131		45	45	20	1945	07	08	08	12	07	10	09	+0.34	+0.98	+0.66
(e) D.L.& W. 7 1/2" x 13" D.S. Diamond Bottom Tie Plate; 1:40 Cant, 1/2" Eccentricity																				
134.5	E.B.	-1.42	2°-02'	2 1/4	131	1935	-	45	slow	1941	10	10	10	11	10	11	10	+0.50	+0.57	+0.54
135.0	E.B.	-1.42	2°-12'	1 3/4	131	1935	-	50	slow	1941	07	05	06	06	06	06	06	+0.93	+0.47	+0.67
135+	E.B.	-1.42	3°-55'	3	131	1935	45	50	40	1941	05	05	05	10	06	08	06	+0.50	+1.09	+0.80
136.0	E.B.	-1.42	4°-32'	4	131	1934	30	35	30	1941	13	08	11	14	09	12	11	+1.00	+0.96	+0.98
136.0	E.B.	-1.42	4°-32'	4	131	1934	30	35	30	1932	19	14	17	26	12	19	18	+0.83	+1.32	+1.08
98.9	E.B.	-1.33	8°-30'	6	131	1943	35	35	35	1943	06	02	04	25	04	15	10	+1.40	+2.09	+1.75
98.9	W.B.	+1.33	8°-30'	5	131	1937	35	30	20	1943	07	03	05	21	03	12	08	+1.46	+2.14	+1.80
Chesapeake & Ohio Railway 7 3/4" x 13" D.S. Flat Bottom Tie Plate; 1:40 Cant, 1/4" Eccentricity																				
423.0	E.B.	0.0	2°-00'	2	131	1938	60	60	50	1938	20	15	18	18	14	16	17	+0.56	+0.52	+0.54
423.0	E.B.	0.0	2°-00'	2	131	1938	60	60	50	1942	13	10	12	11	11	11	12	+0.54	+0.25	+0.40
361.0	E.B.	+0.18	2°-30'	3	131	1939	60	60	25	1939	32	25	29	28	19	24	27	+0.52	+0.67	+0.60
358.1	E.B.	+0.18	3°-00'	4	131	1938	60	60	35	1938	36	26	31	33	19	26	29	+0.60	+0.84	+0.72
424.1	E.B.	-0.10	3°-30'	5	131	1938	60	60	50	1938-41	24	10	17	15	13	14	16	+1.15	+0.40	+0.78
382.2	W.B.	-0.40	4°-07'	4	131	1939	50	50	25	1939	17	07	12	14	06	10	11	+1.16	+1.12	+1.14
410.2	E.B.	+0.38	5°-30'	5	131	1943	50	50	20	1938-42	34	20	27	28	04	16	22	+0.81	+1.87	+1.34
383.0	W.B.	-0.40	5°-45'	5	131	1939	50	50	35	1939	26	08	17	22	09	16	17	+1.41	+1.16	+1.29
164.5	*1 Trk.	-0.09EB	6°-30'	4	131	1938	50	45	40	1936-39	45	15	30	34	14	24	27	+1.33	+1.16	+1.25
Southern Railway System (C.N.O.& T.P. Ry.) 7 1/2" x 12" D.S. Flat Bottom Tie Plate; 1:40 Cant, 1/2" Eccentricity																				
159.0	S.B.	-1.90	4°-00'	4	130	1931	55	50	45	1938	22	24	23	26	08	17	20	+0.42	+1.54	+0.98
225.0	S.B.	-1.14	5°-15'	6	130	1937	50	45	40	1937	32	28	30	28	21	25	27	+0.63	+0.79	+0.71
225.0	N.B.	+1.14	5°-15'	5	130	1937	50	40	35	1937	33	20	27	21	24	23	25	+0.99	+0.37	+0.68
226.2	S.B.	+0.44	5°-20'	6	130	1937	50	40	35	1937	41	18	30	27	23	25	27	+1.29	+0.66	+0.98
Illinois Central System 7 3/4" x 11" D.S. Flat Bottom Tie Plate; 1:40 Cant, 3/8" Eccentricity																				
**L-333	S.B.	+0.50	4°-00'	4	112	1944	45	45	20	1944	08	06	07	16	06	11	09	+0.63	+1.26	+0.95

(a) + = Ascending in the direction of traffic; - = descending.
(b) AREA Sections.
(c) F.E. = Field end of tie plate; G.E. = Gage end.
(d) + = Outward from the centerline of rail base; - = inward.
(e) Penetration data exclude depth of ribs.
* James River Line.
** From tie plate design service test data taken near Curve, Tenn. in 1948.

Table 2

Service Test of Mechanical Wear of Ties with Seven Designs of Tie Plates for 131 lb. R.E. Rail on C.N.O. & T.P. Ry., Mile 326 (Southern Ry. System) Near Chattanooga, Tenn.

Tie Plate Design No.	Tie Plate Dimensions in.	Rail Seat	Tie Plate Penetration from Nov. 1944 to June 1949 in 0.001 in., 97 million gross tons of traffic											
			2 Anchor Cut Spikes					No Anchor Spikes					All Tie Plates	
			Inner or East Rail		Outer or West Rail		Both Rails	Inner or East Rail		Outer or West Rail		Both Rails	Both Rails	
			Field End	Gage End	Gage End	Field End	Mean	Field End	Gage End	Gage End	Field End	Mean	Mean	Percent Loose Plates
6° Curve - Creosoted Oak Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	89	90	79	106	91	100	81	88	108	94	93	56
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	89	79	78	117	91	81	75	69	135	90	91	49
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	80	72	69	107	82	95	79	73	120	92	87	48
831-X	7 1/2 x 14 x 3/4	Rolled Circular	83	66	68	97	79	79	75	79	110	86	83	40
420	7 3/4 x 14 x 7/8	Flat	76	89	62	105	83	93	78	71	140	95	89	70
Plan 5	7 3/4 x 13 x 27/32	Rolled Circular	86	85	81	103	89	96	87	79	104	92	91	53
405	8 x 12 x 3/4	Rolled Circular	-	-	-	-	-	74	77	74	105	83	83	43
*405-A	8 x 12 x 3/4	Rolled Circular	-	-	-	-	-	84	167	136	155	135	135	57
Tangent - Creosoted Oak Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	83	91	86	76	84	69	87	70	80	77	81	62
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	84	73	59	85	75	88	70	68	87	78	77	64
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	78	69	58	78	71	74	48	58	63	61	66	71
831-X	7 1/2 x 14 x 3/4	Rolled Circular	84	61	65	74	71	73	63	52	69	64	67	41
420	7 3/4 x 14 x 7/8	Flat	84	71	68	72	74	62	69	64	75	68	71	84
Plan 5	7 3/4 x 13 x 27/32	Rolled Circular	73	75	89	82	80	70	68	63	73	69	75	55
405	8 x 12 x 3/4	Rolled Circular	-	-	-	-	-	69	76	77	65	72	72	78
Tangent - Creosoted Pine Ties														
831	7 1/2 x 14 3/4 x 31/32	Rolled Circular	75	102	107	86	93	98	129	123	101	113	103	77
831-Z	7 1/2 x 14 x 31/32	Rolled Circular	55	106	101	87	87	68	101	86	89	86	87	70
831-Y	7 1/2 x 14 x 7/8	Rolled Circular	88	90	88	67	83	84	97	86	97	89	86	57
831-X	7 1/2 x 14 x 3/4	Rolled Circular	60	82	92	74	77	51	75	69	85	70	74	75
420	7 3/4 x 14 x 7/8	Flat	70	73	72	96	78	79	106	73	96	89	84	82
Plan 5	7 3/4 x 13 x 27/32	Rolled Circular	79	87	90	74	83	76	103	85	107	93	88	50
405	8 x 12 x 3/4	Rolled Circular	-	-	-	-	-	61	81	97	82	80	80	59

Note: All tie plates have 3/8" eccentricity except design 831 has 1/2" and Plan 5, 1/4".
All tie plates have flat bottom, except design No. 405-A has three transverse ribs.
* Penetration measurements include cutting of the ribs into the ties.

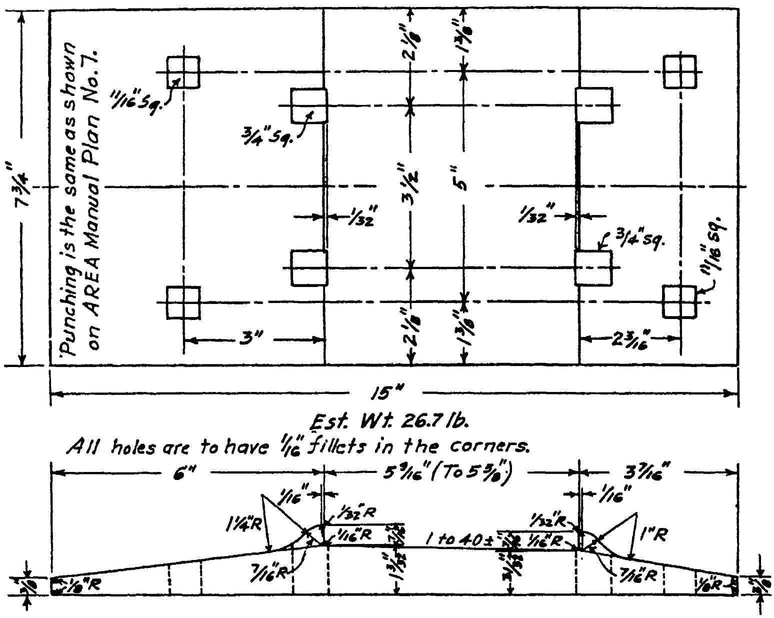


Fig. 4.—15-in. Tie Plate for 5½-in Rail Base. 1¼-in. Eccentricity. 1 to 40 Cant.

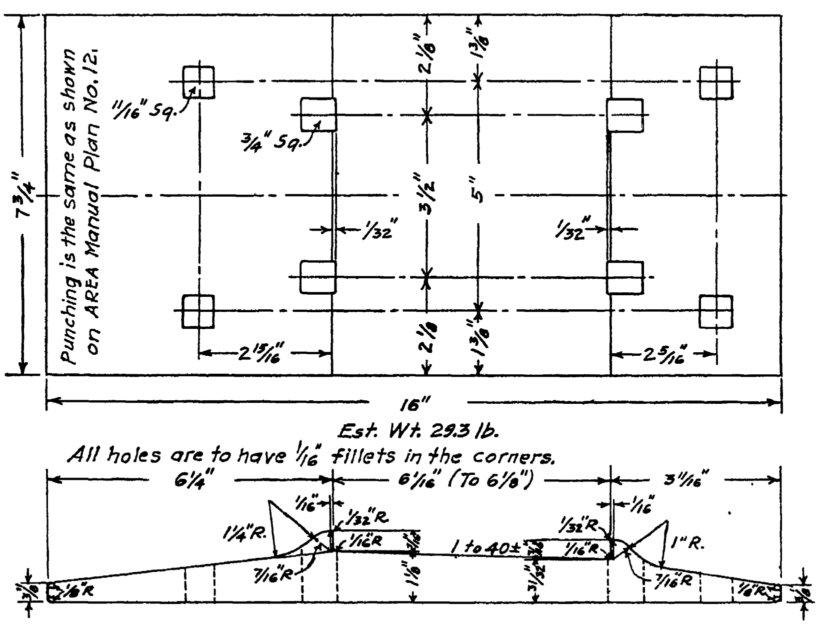


Fig. 5.—16-in. Tie Plate for 6-in. Rail Base. 1¼-in. Eccentricity. 1 to 40 Cant.

Tie Plate Service Test Measurements

Foreword

This progress report covers the performance of seven designs of tie plates for 131 RE rail which were placed on new ties in tangent track and a 6-deg. curve in November 1944 on the single-track main line of the C. N. O. & T. P. Ry. (Southern Railway System), approximately 12 miles north of Chattanooga, Tenn., and includes test data for the period ended May 30, 1949, in which the traffic amounted to 97 million gross tons.

Previous reports covering this test have been presented in the Proceedings, Vol. 47, 1946, pages 491–514 and Vol. 50, 1949, pages 40–47.

Tie Plate Penetration

These data show the depth of plate cutting into the ties and are summarized in Table 2. The north half of each test panel of track, except for the 12-in. tie plates, has two cut spikes for anchors, while other portions of the test sections have only line spikes. There were no significant differences in the cutting of any pattern of tie plate with or without anchor cut spikes. Other tests have demonstrated that cut spikes used as anchors were not effective in reducing mechanical wear of ties. There has been no acceleration in the rate of plate cutting relative to the traffic carried by the test track. The average tie plate penetration for the outer rail is slightly greater than for the corresponding inner rail of the 6-deg. curve. There is little evidence of damaging pressures on the ties except at the field end of some of the plate designs in the outer rail of the curve. In the tangent test section the penetration on the oak ties was 84 percent as large as on the pine ties.

Table 2 showing the mean penetration values to date for all tie plates in a test panel, does not indicate that differences in tie plate design, such as length, thickness and type of rail seat, have had any appreciable effect on the rate of tie wear. Except for one test panel with creosoted pine ties, the average tie wear has been less than 0.10 in. which is not considered excessive for the tonnage carried.

Most of the trains were hauled by multiple-unit diesels and practically all movements over the test stretch were above the balanced speed of 40 mph. This favorable operating condition also manifested itself in the condition of the head of the low rail, in that little flow of metal toward either side of the head had occurred after the passage of 97 million gross tons of traffic. The centroid of the tie plate loads, as computed from penetration data for the four panels of 14-in. tie plates on the curve (all having an eccentricity of ⅜ in.) was 0.93 in. and 0.50 in. outside of the center line of the rail base for the outer and inner rails, respectively.

Tie Plate Bending

Measurements were taken, as explained in previous reports, to determine whether the ends of the tie plates had become bent up to any extent during the traffic service period. No such bending was found in any of the designs included in the test. So far even the thinnest tie plates used (design 831–X) have produced a sufficiently uniform pressure along the plate length to prevent undue damage of the wood fibers under the rail base where the bearing pressures are greatest. This condition may change with further service use.

Gage of Track

A record of the track gage based on measurements at six points in each panel of track is shown in Figs. 6 and 7 for the curve and tangent sections, respectively. Ir-

Use of Special Tie Plates

These special tie plates are to be used only where needed. The need for these plates on a particular curve can readily be determined by observing the plate cutting and the canting of the rail, as well as from the past performance of the curve. On the Lackawanna near Scranton, Pa., where it is necessary to re-adze and set up the inner rail every four years on many of the curves, the special plate for the inner rail should materially reduce the cost of maintaining the curves. In some cases where all trains run well above balanced speed, use of the plate might be confined to the outer rail. For some curves the special plate will be needed on both rails. The plate should not be used on both rails of a curve if they will cause the gage to tighten appreciably.

These tie plates should materially reduce the expense of re-adzing and regaging curves and extend the service life of tie where it is needed the most. Further, by holding standard gage on curves for a longer period, it is believed this will increase the life of the inner rail where the speed is slow in relation to the balanced speed because wide gage accelerates the lateral flow of the metal in the rail head.

To avoid tight gage on the spirals of the curves where the special tie plates are used, they should only be placed on about one-half of the length of each spiral adjacent to the simple curve, unless experience with the plates indicates that different limits will be more effective. Possibly an inspection of the plate cutting will indicate to what extent the plates should be used on the light portion of spirals.

Alternative Methods of Correction

Gage rods, buck plates and other devices are reasonably effective in holding the rail base to good gage but the rails on curves continue to cant outward because of unequal tie plate penetration. Tie pads and effective types of hold-down fastenings that reduce tie wear to a negligible amount are beneficial in minimizing rail canting and the resulting gage widening on curves. However, the service life of tie pads and many types of tie plate fastenings has not been established and there is some uncertainty as to the ultimate economy of the additional expenditures required.

Reduction of the elevation is beneficial to the maintenance of curves, but is only a partial remedy and cannot be utilized extensively because of the attendant restrictions on the speed of operation.

Recommendations

Because it is believed that considerable economy can be effected, particularly on railroads traversing mountainous and foothill areas, in reducing the expense of maintaining gage, the ties and the inner rail itself on a large mileage of curves, tie plate plans Figs. 4 and 5 are offered for consideration for use on curves where observations of the plate cutting or past experience indicates that one or both rails cant outward sufficiently to cause too frequent re-adzing and regaging.

Acknowledgement

The Association is indebted to the railroads mentioned in this report for cooperation and assistance rendered in assembling the field data.

Report on Assignment 7

Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

Blair Blowers (chairman, subcommittee), L. L. Adams, C. A. Anderson, A. L. Bartlett, F. J. Bishop, J. A. Blalock, H. J. Bogardus, A. E. Botts, H. F. Busch, E. W. Caruthers, H. B. Christianson, E. D. Cowlin, H. F. Fifield, J. W. Fulmer, C. E. R. Haight, J. P. Hiltz, J. W. Hopkins, A. F. Huber, J. de N. Macomb, E. E. Martin, F. H. Masters, T. W. Meushaw, J. A. Reed, M. K. Ruppert, Troy West, M. J. Zeeman.

This is a progress report, presented as information, and includes the tie plate hold-down fastenings test installations on the Louisville & Nashville Railroad and the Illinois Central Railroad, and also measurements of tie wear for an installation of GEO track construction on the Missouri Pacific Railroad.

Tests on the Louisville & Nashville Railroad

This installation, which was largely built in August 1947 and extended in 1948, has been reported in the Proceedings, Vol. 50, 1949, pages 595–623. Some additions and changes to existing test sections were made in 1949. A description of this work, as well as the results of the general inspection, will be given on the following pages.

Additions in 1949

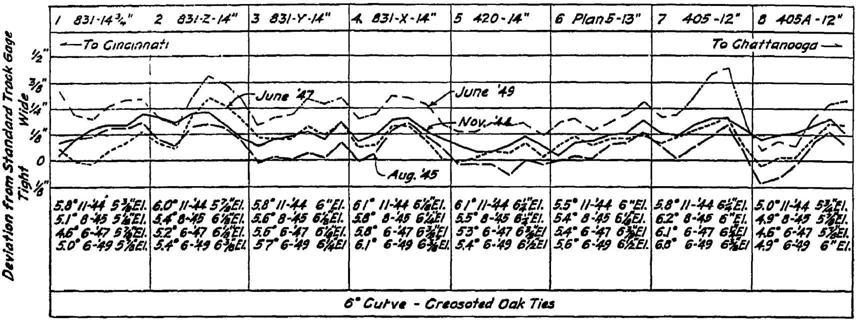
Seven new test sections were installed in August and September 1949, and designated as Nos. 28 to 34, incl. Three two-panel sections of tie pads with creosoted oak ties were placed on the north end of the long test curve. These sections included one new type of tie pad, one similar to a type previously used but furnished by a different manufacturer, and another one identical with one of the 1947 installations, but applied with an 11-in. tie plate. Sections 31 to 34, incl., were installed in tangent track with creosoted oak ties and the 14-in. AREA tie plate for the 6-in. rail base. This work involved two panels each of the G. & H. No-Creep rail anchor and the tie plate Lock Spike construction, 12 ties with Farbertite coating on the adzed surface and five ties with the plates attached with the Borden Company's Chemical Division adhesives under ideal conditions. A plan of the entire test installation is shown in Fig. 1, and Table 1 gives descriptive information for each test section.

Installations on Long Test Curve

Section 28

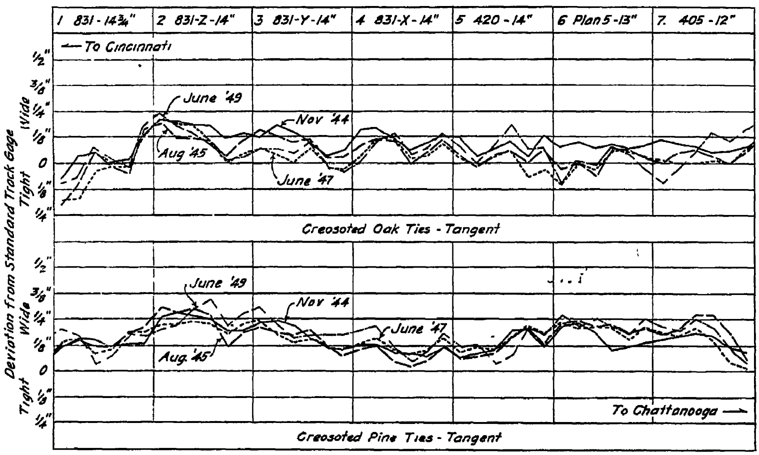
This construction, shown in Fig. 2, consists of 13-in. wool felt pads, ¼ in. thick, furnished by the Western Felt Works, Chicago, AREA plan 5B* tie plates with a rolled circular rail seat and four cut line spikes, without anchors. The pads were impregnated with a chemical to increase their resistance to water, mildew and fungus. Test data from the manufacturer indicate the pad has a low tensile strength. This type of tie pad is softer and more pliable than the others being tested.

* Withdrawn from the Manual in 1948.



All Track Panels are 39 ft. in length and divide at the joints in the outer rail.
Each Tie Plate has 3 Line Spikes and, in addition, 2 Cut Spikes for Anchors in the North Half of Each Panel of Track, except in Panels 7 and 8.

Fig. 6.—Gage, Curvature and Elevation of Each Panel of Test Track on the 6-deg. Curve, C. N. O. & T. P. Ry., Mile 326.



Each Tie Plate has 2 Line Spikes and, in addition, 2 Cut Spikes for Anchors in the North Half of Each Panel of Track, except in Panel 7. Panels are divided at the joints in the west rail.

Fig. 7.—Gage of Each Panel of Test Truck on Tangent, C. N. O. & T. P. Ry. Mile 326.

regularity of the track gage has increased, particularly on the curve. The mean gage on the tangent test portions was about the same as when the test was begun in November 1944. In the eight panels of the curve the gage has widened an average of 0.10 in. On the curve (Fig. 6) in panels 1 to 4, inclusive, the gage has widened more in the south portions where no anchor spikes were used. So far, in panel 8 where the 12-in. tie plates had three transverse ribs on the bottom, the average gage was about the same as when the test was started. Anchor spikes were not used with the 12-in. plates because no holes were provided.

Conclusions

Several more years of traffic will evidently be required before enough tie wear has developed to justify conclusions regarding the various features of tie plate design being studied in these tests.

Table 1 - Description of Test Sections as Shown in Fig 1

Section No	No of Test Ties: Creo Oak Curve	Creo Oak Tang	Pine Tang	Total	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pads (131-lb RE Rail)
1					Adhesives-no anchor spikes-subdivided as follows:
1.1	11	6	12	29	Beckosol No 40 Heated and applied to bottom of tie plate with a paddle
1.2	9	9	9	27	Waterproofing Asphalt, AREA Specifications. Applied in the same manner as above
1.3	0	4	6	10	CASCO Flexible Cement NT-442. Applied to tie plate and tie in the field
1.4	3	3	6	12	NT-442 Cement applied to tie plate as a primer and CASCO PHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	9	27	Same as subsection 1.4 except the tie plates were cemented to the ties before creosoting
1.6	2	0	0	2	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating, designated No 52
1.7	2	0	0	2	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating modified to further reduce flow, designated No.53
1.8	2	0	0	2	Same as No 53 except the asphalt was formed around brass screening, designated No 54
1.9	2	0	0	2	Same as No 53 except the asphalt was formed around 1/4 in mesh galvanized screening, designated No.55
1.10	6	0	0	6	Salvated Sealz Coating, no anchor spikes
2	59	47	48	154	No anchor spikes
3	24	31	32	87	1-ply Bird tie pads, no anchor spikes
4	47	32	32	111	5-ply Bird tie pads, no anchor spikes.(South 40 pads on curve were replaced with Duck-Burlap type Aug 1948)
5	49	31	32	112	7-ply Bird tie pads, no anchor spikes (North " " " " " " " " " " " ")
6	0	32	32	64	No anchor spikes, 2 Racor Drive Tight (Sandberg) line spikes
7	58	32	32	122	2 each of Racor Drive Tight (Sandberg) line and anchor spikes (Anchor spikes replaced in Nov 1948)
8	60	31	32	123	2 cut spikes for line and 2 Racor Drive Tight (Sandberg) anchor spikes.(Anchor spikes replaced in Nov. 1948)
9	59	48	48	155	2 each of cut spikes for line and anchors
10	59	47	49	155	2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153	2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153	2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2	2 cut spikes for line and 2 cone neck type Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141	2 cut spikes for line and 2 Elastic Spikes of design No.93 for anchors
13	12	0	0	12	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors
14	47	24	24	95	2 cut spikes for line and 2-3/4 in thru bolts with single coil spring washers for anchors (Applied in the field)
15	48	24	24	96	2 cut spikes for line and 2-3/4 in thru bolts with single coil spring washers for anchors (Applied in shop under load)
(a)16	60	47	48	155	2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors
17	60	47	47	154	2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve
18	58	48	48	154	No anchor spikes Erie RR standard 13 in single shoulder tie plate with diamond bottom
(a)19	59	0	0	59	2 cut spikes for line and 2 screw spikes with double coil spring washers for anchors using above Erie RR tie plate
20	0	47	47	94	2 Thompson Rail and Tie Plate Clamps with screw spikes and triple coil spring washers for line and anchor spikes on tangent
21	47	47	47	141	Fabco Track Pads, 1/4 in. Thick, no anchor spikes
22	0	48	48	96	2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil spring washers for anchors
23	24	24	23	71	L & N RR Standard 14 in tie plate with 2 each of cut spikes for line and anchors
24	24	24	24	72	L & N RR Standard 14 in tie plate with 2 each of cut spikes for line and anchors and a Rails Co clip on alternate tie plates
25	47	0	0	47	Johns-Manville Track Pads; 1/8 in. thick in North Panel, 1/4 in. thick in South Panel, no anchor spikes
26	49	0	0	49	Lackawana DS Dia Bottom 13 in tie plates, 2 cut spikes for line and 1 anchor only
27	48	0	0	48	Burkart Fiber Pads, no anchor spikes
28	48	0	0	48	Western Felt Works wool felt pads, no anchor spikes
29	48	0	0	48	Bird Fiber-Rubber pads, no anchor spikes
30	48	0	0	48	5-ply Bird Duck-Burlap pads, 11 in tie plate, no anchor spikes
31	0	48	0	48	G & H Controls, No-Creep rail anchors on alternate ties
32	0	12	0	12	Farbertite coating on ties, no anchor spikes
33	0	5	0	5	14 in tie plates cemented to ties with the same Borden Co. adhesives as used in Section 1.5, no anchor spikes
34	0	48	0	48	2 cut spikes for line and 2 Tie Plate Lock Spikes (Revised) for anchors
	1353	997	901	3251	Totals

Notes. AREA Plan 5B (Modified) 13 in tie plate with flat rail seat was used in all sections except as follows. (1) Penn RR standard 14-3/4 in tie plate cut to a length of 13 in for section 17, (2) Erie RR standard 13 in single shoulder, diamond bottom tie plate for sections 18 and 19, (3) L & N RR standard 14 in tie plate for sections 23, 24, 31, 32, 33 and 34, (4) S.H. Plan 5B 13 in tie plate with rolled circular crown for sections 1.10, 27, 28, 29 and also in section 30 except cut to a 11 in length, (5) D L & W 13 in double shoulder diamond bottom plate for section 26

In the sections on the curve where no anchor spikes were provided, 4 cut spikes per tie plate were used as line spikes

(a) In the north half of each portion of these test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used

All test sections were installed in 1947 except as follows: (1) sections 1.10, 25, 26, 27 and section 21 (curve only) were built in 1948; (2) sections 28 to 34, incl. were placed in 1949

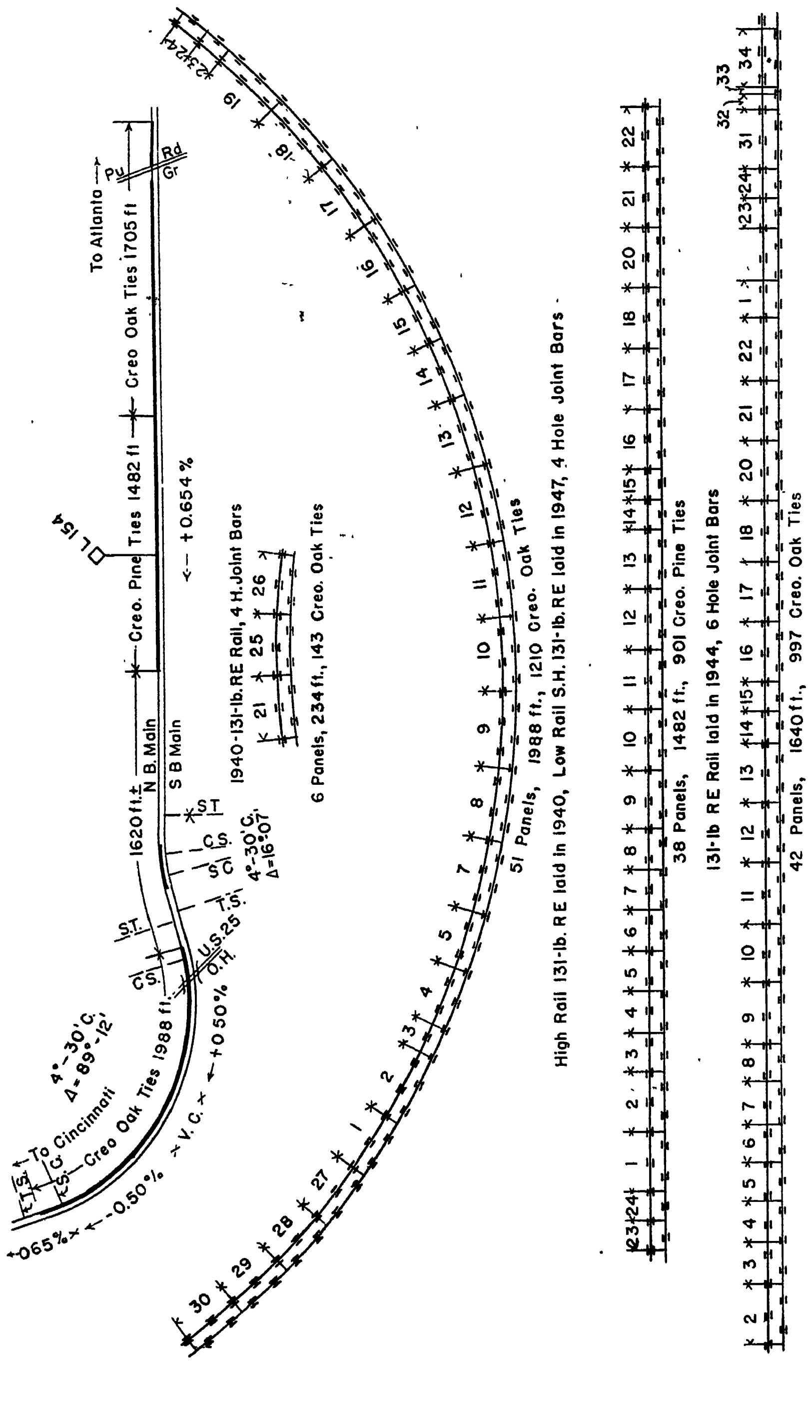


Fig. 1.—Plan of Test Track.

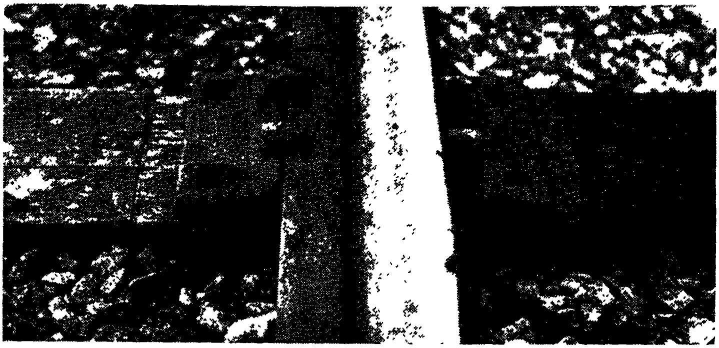


Fig. 2.—Section 28, 13-in. Wool Felt Tie Pad.

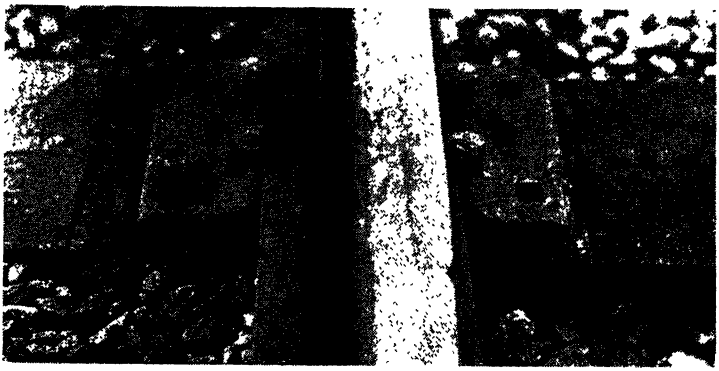


Fig. 3.—Section 29, 13-in. Bird Fiber-Rubber Tie Pad.

Fig. 4.—Section 30, 11-in., 5-ply Bird Duck-Burlap Tie Pad.

Section 29

Bird fiber-rubber tie pads, 13 in. in length, were used in this section with the same track construction as described in section 28. This pad is similar in composition to the Fabco pad but has the special asphalt coating used on the Bird duck-burlap pads. A view of this construction may be observed in Fig. 3.

Section 30

In this section, an 11-in. 5-ply Bird duck-burlap pad was used with a 13-in. plan 5B tie plate cut to an 11-in. length by shearing 1-in. off of each end. The pads are of similar make-up to those used to replace 40 original duck-felt pads in section 4 on the long test curve in 1948. The use of the 11-in. pad is for the purpose of determining if the tie wear will be less than when longer plates are used without pads. Fig. 4 is a typical view of this section.

Installations in Tangent Track

Section 31

G & H Rail Controls, Inc., suggested the fastenings used in this section with the 14-in. tie plate. Twenty-four ties, alternately spaced except where rail joints interfered, have the following construction: One G. & H. No-Creep rail anchor on the gage end of each tie plate, one cut spike for line on the field side of the rail and two Oliver tie plate drive spikes (without spring washers) as anchors. The Oliver spikes are of the same design as used in section 22. The other 24 ties have two line spikes, without anchors. The special construction is shown in Fig. 5. The lugs were electric welded to the plates by a local welder at London, Ky., under the supervision of C. J. Hunnicutt, vice-president, G & H Rail Controls. The merits of this device acting as a rail anchor cannot be determined in 78 ft. of track. However, information will be developed on the relative rate of plate cutting for the special fastenings and cut spike construction.

Section 32

This section, consisting of 12 creosoted oak ties with 14-in. tie plates and two cut line spikes, utilizes a new product for waterproofing the adzed surfaces. A paddle coat of Farbertite was placed on the adzed surface and the bottom of the plate after sweeping the ties with a broom and wire brushing the plates. Farbertite is a plasticized coal tar product compounded for the protection and preservation of steel, concrete, wood, glass, aluminum, etc. It is said to have good bonding properties, good resistance to weather and brine and will not run in summer or crack in winter. It is manufactured by the Rochester Consolidated Corporation.

Section 33

At the request of the Borden Company, Chemical Division (formerly the Casein Company of America) arrangements were made for this organization to attach 14-in tie plates to six oak ties, following the best known procedure for the work. Casco Flexible Cement NT–442 and Casophen RS–216, as described for subsection 1.5 in the previous report, were used in the gluing operation. The tie plates were ground on the bottom to a true surface which was later cleaned immediately before applying NT–442 as a primer coat. Six untreated but seasoned oak ties, prebored but not adzed, were furnished to Gamble Brothers, Louisville, Ky., who performed the work of attaching the plates in their plywood plant as directed by the Borden Co. One tie was not used, as an error was made in setting the plates for standard track gage. The five ties left were creosoted and shipped to the test location. One plate on each of two ties was knocked off

Alterations in 1949

On December 1, 1949, changes were made in two of the original test sections which are described below.

Section 2

This section in the tangent portions with creosoted oak and pine ties has the 13-in. AREA Plan 5B (modified) tie plate with 2 cut line spikes and no anchor spikes.

The Dunne Rubber Company, Ashtabula, Ohio, has developed a rubber spike cushion designated as the Dunne Spike Cushion. It is a molded product having a square hole through which the line spike is driven and has a projection reinforced with fabric which lies between the throat of the spike and the rail base. It is said to be a shock absorber between the spike and the rail base for the purpose of preventing the spike from resting on the rail base and being pulled up from the tie by the wave action of the rail.

These spike cushions were applied to the line spikes of the north 24 ties in each of the tangent portions of this section. The line spikes after being pulled were driven in the unused prebored line holes for the opposite stagger. The cushions will be inspected each year to determine whether they are of any benefit in preventing uplift of the line spikes. It is not expected that this device will effect any reduction in mechanical wear of ties.

Section 6

In the original installation, this section had 32 each of creosoted oak and pine ties in tangent tracks with two Racor Drive Tight line spikes, no anchor spikes and the same tie plate as used in section 2.

The sponsor of this patented spike, the Ramajo–Ajax Division, American Brake Shoe Company, has determined from laboratory and other tests that the spike used in the line position, only, does not eliminate horizontal movement of tie plates for a long period. By tapping with a hammer the research staff found 70 plates out of 128 loose on the ties in September 1949, about two years after installation.

The sponsor has developed a new design of Racor spike for use in the anchor position only, as shown in Fig. 7. Laboratory tests by the sponsor indicate that this experimental design will be effective when driven in either the standard 11/16-in. square tie plate hole or a ¾-in. dia. round hole if desired, and the length will be adequate for normal use.

The spike has been designed for economical production and the manufacturer expects to offer it at a price very close to that of the common cut spike.

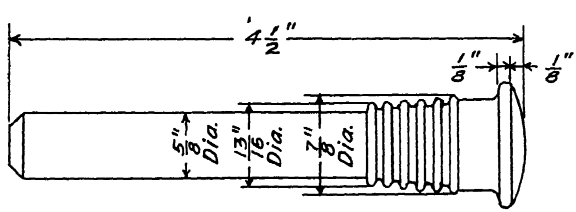


Fig. 7.—Section 6, Racor Stud.

Fig. 5.—Section 31, 1 G & H No-Creep Rail Anchor and 2 Oliver Tie Plate Drive Spikes on Alternate Ties.

when the ties were unloaded. This section consists of five ties, two cut line spikes per plate and eight plates cemented to the ties. It was the purpose of the sponsor of this experiment to determine if it will be possible to hold the tie plates in place under traffic for several years.

Section 34

This section consists of 48 creosoted oak ties, 14-in. tie plates with two cut spikes for line and two tie plate lock spikes of revised design for anchors, shown in Fig. 6. The original design of tie plate lock spike (see Proceedings, Vol. 50, 1949, Fig. 15, page 611) was applied to only 12 ties in section 13 on the long test curve in 1947, which also included the Elastic spikes. It was decided to install a longer section to better judge the performance of the lock spikes and also to utilize the new design which the manufacturer claims to be superior to the old one and more economical to produce. Asphalt roofing paint was applied to the bottom of the plates and the adzed surfaces of the south 24 ties in this section. In this section the line and anchor spikes could not be staggered properly because only two prebored holes were provided for the anchor spikes.

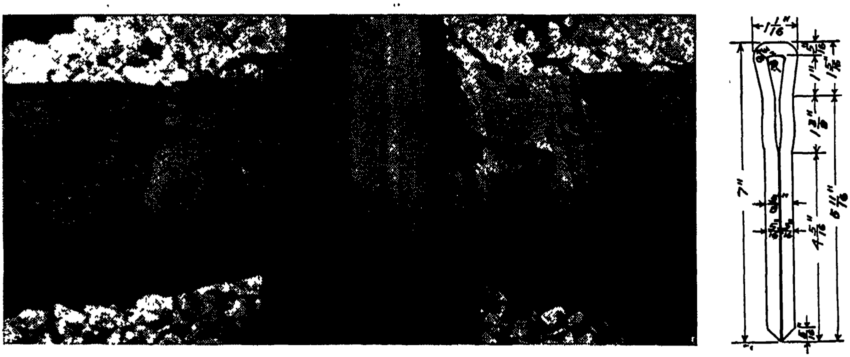
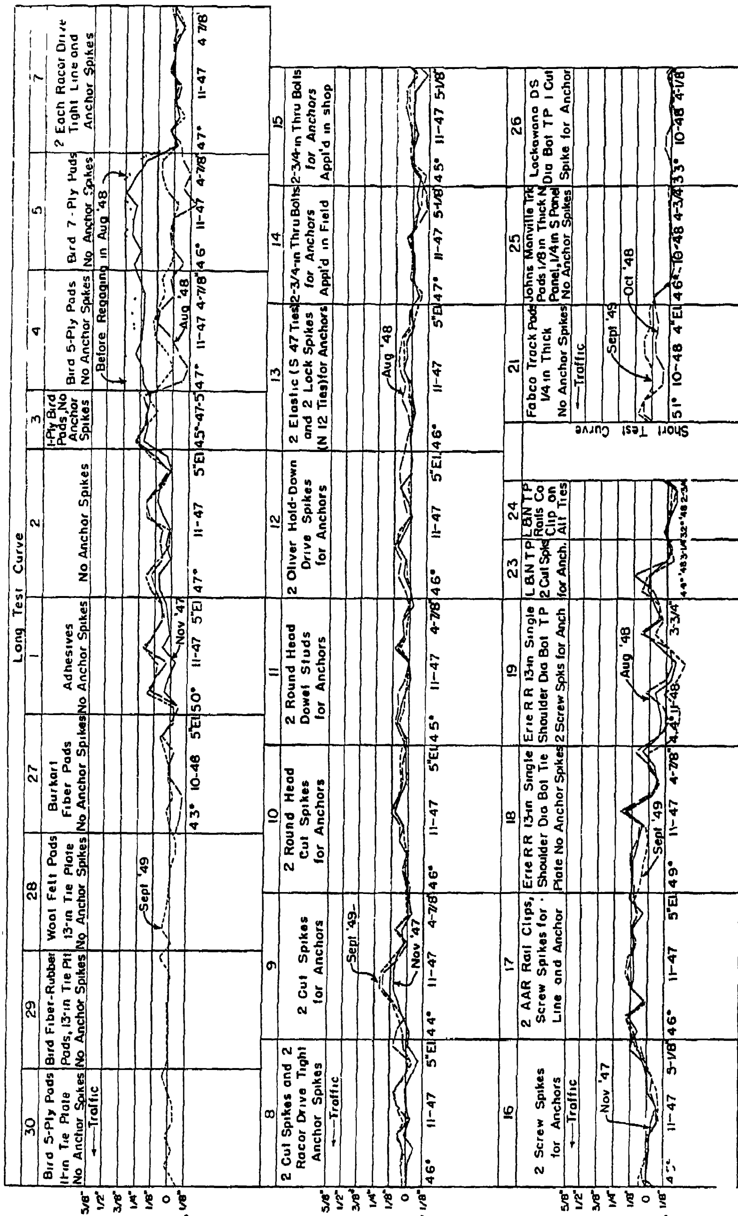


Fig. 6.—Section 34, 2 Tie Plate Lock Spikes.



Note All test sections have 13-in Plan 5B (Modified) tie plates with flat rail seat except those shown otherwise and as follows Sec 17, Penn R R 14-3/4 in tie plate sheared to a 13 in length; Sections 23 and 24, 14 in AREA tie plate, Sec 26, 13 in Lackawana double shoulder diamond bottom tie plate, Sections 27, 28 and 29, S H Plan 5B with rolled crown and also in Sec 30, except cut to 11 in length. All sections without anchor spikes have four line spikes and sections with anchor spikes have two line spikes Sec 26 has 2 cut line spikes and 1 anchor spike

Fig. 9.—Gage, Curvature and Elevation of Each Section of Test Track on the 4-deg. 30-min. Curves, Mile L–154, L. & N. R. R., near London, Ky.

Section 26

This section on the short test curve, placed in 1948, originally had two each of cut line and anchor spikes. Later, it was decided to remove the field anchor spike in order to determine if the Lackawanna diamond bottom tie plate would hold gage with three spikes as well as the flat bottom plates with four cut spikes. This change was made in January 1949. One of these plates is shown in Fig. 8.

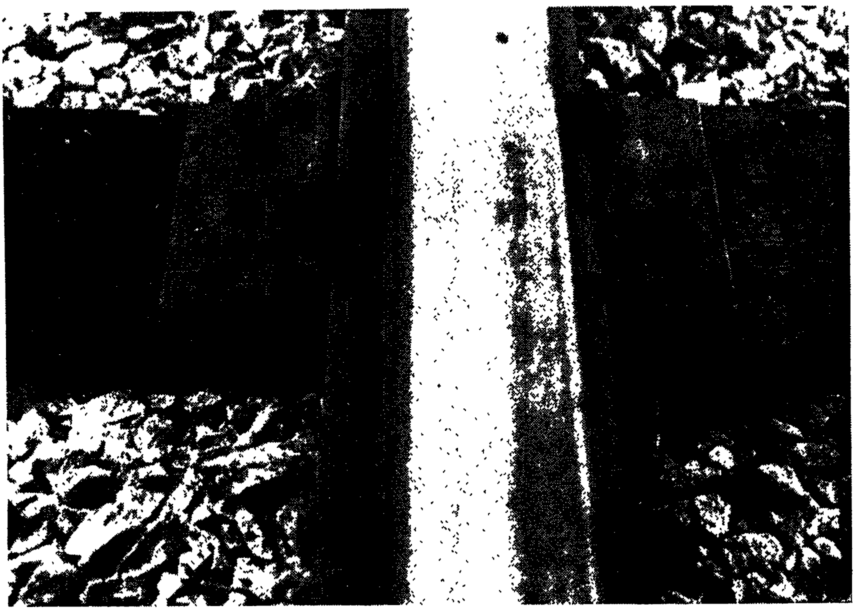


Fig. 8.—Section 26, 13-in. D. L. & W. R. R. Diamond Bottom Tie Plate.

1949 Inspection

Track Gage on Test Curves

Track gage measurements have been taken at four points in each panel of track on the two test curves annually and this information is shown in Fig. 9. In sections 28, 29 and 30 the initial gage readings for those new pad sections were taken at the end of the day of installation in order to determine if any gage widening occurs during the early period of seating of the tie plate and pad. Gage in the three pad sections checked in December 1, 1949, was practically the same as on September 20, 1949, the date of installation. In sections 4 and 5 with the Bird 5 and 7-ply pads, respectively, there has been a little gage widening since regaging those panels in August 1948. The principal gage change occurred where the gage was spiked tight at that time. Some tightening of the gage may be observed in sections 18 and 19 with the Erie Railroad's single-shoulder diamond bottom tie plates. This is explained by the failure of both the high and low rails to bear against the tie plate shoulder. This condition affects the line as well as the track gage, and it is difficult to predict what the gage will be under load. In general, the gage was holding well on the test curves.

Fig. 10.—Section 25, 13-in. Johns-Manville Asbestos-Rubber Tie Pad, 1/8 in. Thick.

horizontal movement of the tie plates. This was indicated by the fact that 55 percent of the tie plates were loose on the ties.

In 1948 a reinstallation was made of the north 23 ties in both portions of section 20 (Thompson rail and tie plate clamp) in order to repeat the test with the wood hardener in the prebored holes for the screw spikes. In September 1949 the loosening torque was measured for 20 to 28 screw spikes with and without wood hardener in both oak and pine ties. The average torque in the oak tie section was the same with or without the wood hardener, and in the section having pine ties the torque with wood hardener was 30 percent greater than it was on spikes where no chemical was applied.

In the other test sections, the condition of the various tie plate fastenings was good. No general tightening or tapping down of the anchor fastenings was needed.

Tie Pads

This service test has been of insufficient duration to warrant conclusions regarding the relative expected service life, effectiveness in minimizing tie abrasion and overall economy of the several types of tie pads. However, the following comments seem justified.

1. Tie pads should be made of durable material capable of withstanding the elements and service conditions for many years.

2. Their mechanical strength must be sufficient to avoid pulling apart and working out, separation of the plies, ripping at the spikes and an unequal compression at the ends of the tie plate to such an extent as to cause an appreciable canting of the rail outward on curves and widen the gage of track.

3. Pads should be sealed to the ties with an inexpensive material to avoid movement on the ties and to keep out water, sand, dirt, etc.

Other Observations

In the 1947 installation of sections 1.3, 1.4 and 1.5, 98 tie plates 13 in. in length, were attached with cements furnished by the Casein Company of America (now the Borden Company, Chemical Division), and by October 1948 all tie plates had broken bond with the ties except nine in section 1.5 on tangent track with softwood ties (see Table 1). The last two of the nine tie plates broke bond in June 1949, 21 months after insertion in the track.

The Solvated Sealz coating placed on the ties of section 1.10 in 1948 was in good condition as to weathering, holding its bond with the tie and squeezing into the vacant plate punching and around the edges of the tie plates, except that the plate movement had broken the bond along the edges. So far the performance of that material has been the best of the coatings applied in the field with a brush or paddle.

The several types of tie pads were generally in good condition, except for the following observations:

The five and seven-ply Bird duck-burlap pads placed in the long test curve in 1948 were in good condition. The asphalt coating had squeezed out and formed a heavy bead around the edges, but removal and examination of this bead indicated there was no extrusion of the fabric. One of the five-ply pads was removed from a joint tie in the low rail of the curve and the bearing area was in good condition with no indication of tie abrasion.

The five and seven-ply Bird duck-felt pads placed in 1947, which have been discontinued by the manufacturer because of some extrusion of the intermediate felt plies, showed an increasing tendency for the felt plies to work out in a larger number of pads than in 1948. One of these seven-ply pads was also removed from a low rail joint tie and the condition of the bearing area on the tie was good and no abrasion of the wood had occurred.

The single-ply duck pads with asphalt coating placed in 1947 were made up by Bird & Son at the request of the AAR research staff in its search for an economical tie pad. The manufacturer had concluded from previous service tests that even the three-ply pads were too thin because some of them had ripped at the spikes and worked out from under the tie plate. Twenty-nine of 174 single-ply pads had worked out of place to some extent. The pad movement was generally less than one inch laterally with the rail.

The Fabco pads placed in 1947 continue to show a permanent stretching lengthwise of the tie plate but most of the elongation was under 1 in., averaging about ½ in. The Fabco pads installed on the short test curve in 1948 showed less indication of stretching than those on tangent track after one year's service.

The Johns-Manville asbestos-rubber tie pads installed in 1948 in the short test curve were in good condition except there was some indication that the pads ⅛-in. thick were being cut off where they projected beyond the tie plate ends. Examination of J-M pads that were removed revealed tie abrasion, which suggests that the material was harder than the oak ties. Fig. 10 shows one of the ⅛-in. thick pads where it was being cut off on the field end. This type of pad did not deform easily nor did it seat well on the tie after one year's service.

The Burkart fiber pads were in good condition after 11 months' service on the long test curve.

The Racor Drive Tight spikes were effective in holding the plates to the ties in sections 7 and 8 where anchor spikes were used. Where it was used for line, without any type of anchor spike (section 6) this spike was less effective in minimizing the

TABLE 2. - SERVICE TEST OF MECHANICAL WEAR OF TIES WITH TWO DESIGNS OF TIE PLATES AND THREE KINDS OF TIES IN THE WEST RAIL OF THE MIDDLE TRACK OF THE ILLINOIS CENTRAL SYSTEM, BETWEEN M.P. C-42 AND M.P. C-45, NORTH OF MANTENO, ILL.

Tangent Track - Traffic in both directions. New 131-lb. RE rail with 6-hole joints laid in 1943. All ties 7 in. by 9 in. by 8 ft. 6 in. renewed in 1943.

Mile	Kind of Cross Ties	Number and Kind of Anchor Spikes per Tie Plate	Tie Plate Penetration in 0.001 in. October 1944 to July 1949 (78 Million Gross Tons) — End of Tie Plates: Field	Gage	Avg.
7 3/4 in. by 13 in. by 27/32 in. double shoulder tie plates, rolled circular crown, 1:40 ± cant, flat bottom, level shoulder extensions, eccentricity ¼ in., AREA Plan No. 5B.					
C-43	Creo. Pine	None - - - - - - - - - - - - - -	96	115	106
C-43	Creo. Pine	4 S.S.* - - - - - - - - - - - - -	57	93	75
C-43	Creo. Pine	2 S.S. - - - - - - - - - - - - -	66	75	71
C-43	Creo. Pine	4 S.S. with double coil washers	65	69	67
C-43	Creo. Pine	2 S.S. with double coil washers	67	68	68
C-43	Creo. Pine	4 Cut Spikes - - - - - - - - -	81	108	95
C-43	Creo. Pine	2 Cut Spikes - - - - - - - - -	92	101	97
C-44	Creo. Gum	None - - - - - - - - - - - - -	56	76	66
C-44	Creo. Gum	2 S.S. with double coil washers	21	29	25
C-45	Creo. Oak	None - - - - - - - - - - - - -	54	63	59
C-45	Creo. Oak	2 S.S. with double coil washers	22	18	20
C-45	Creo. Oak	2 Cut Spikes - - - - - - - - -	62	72	67
7½ in. by 14 3/4 in. by 31/32 in. double shoulder tie plates, rolled circular crown, 1:40 ± cant, wave bottom, tapered shoulder extensions, eccentricity ½ in., Penna. R.R. standard.					
C-43	Creo. Pine	None - - - - - - - - - - - - - -	94	120	107
C-43	Creo. Pine	2 S.S. with double coil washers	48	50	49
C-44	Creo. Gum	None - - - - - - - - - - - - - -	79	85	82
C-44	Creo. Gum	2 S.S. with double coil washers	44	46	45
C-45	Creo. Oak	None - - - - - - - - - - - - - -	56	72	64
C-45	Creo. Oak	2 S.S. with double coil washers	41	35	38
C-45	Creo. Oak	2 Cut Spikes - - - - - - - - -	73	81	77

*S.S. = Screw Spike

The tie plate penetration measurements for 90 million gross tons of traffic are shown in Table 3, and the plate cutting with the Elastic spikes was about 20 percent less than that obtained with cut spike anchors. The average penetration measurements for the three types of tie plate anchorage ranged from 0.048 in. to 0.062 in. These values are so small that they can only serve as an indication of the trend in the rates of wear in the next few years.

It should be noted that in both main tracks, all of the tie plate anchor spike holes are 15/16 in. in dia. and that arrangement does not provide as good a fit for the cut and Elastic spikes as the standard 11/16-in. square punching.

4. Pads should be made of a material of sufficient strength to resist the bearing pressures but not hard enough to abrade the tie.

5. Pad thickness should be held to the minimum so that the spikes will not crush the wood fibers laterally and cause wide gage, particularly on curves.

Test Measurements

Initial measurements for the new sections added as well as for making the change in section 6 were completed December 1, 1949. Tie plate penetration measurements for the entire test installation, now embracing a mile of track, were not taken this year. The research staff plans to make those measurements in 1950.

Acknowledgment

The Association is indebted to the Louisville & Nashville for its fine cooperation and assistance in the construction work and taking the field data, and also extends its appreciation to the manufacturers for their assistance in many ways as well as for the donation of the pads and fastenings.

Tests on Illinois Central Railroad

The Illinois Central Railroad is conducting a series of tests north of Manteno, Ill., and the research staff has been checking the installation periodically and reporting its findings to the Association. The first progress report was published in the Proceedings, Vol. 48, 1947, page 648, and last year's report may be found in Vol. 50, 1949, page 624.

Tests on 131 RE Rail

This test stretch covers three miles of tangent in the middle main track, on three kinds of creosoted ties, two lengths of tie plates and seven variations of hold-down fastenings in high speed territory. In these three miles the track was completely rebuilt with new crushed rock ballast, ties, rail and other track material in 1943.

Table 2 gives a summary of the tie plate penetration measurements for the period from October 1944 to July 1949 in which the traffic amounted to 78 million gross tons. In general, the rate of tie wear has shown a moderate acceleration as compared to last year's results. However, the plate cutting is still quite small and in only two sections did it exceed 0.1 in. Generally, there were little differences in the plate cutting for anchor cut spikes and no hold-down fastenings. Installations with both four and two screw spikes and with double-coil spring washers have shown the best performance by reducing the tie plate penetration from 1/3 to 2/3 of that obtained in the corresponding sections without hold-down fastenings. In most instances, sections with identical construction except for the tie plate length showed a greater average penetration for the longer plate. This is attributed to the fact that the 13-in. tie plate has a flat bottom while the 14¾-in. plate has a modified wave bottom which requires 1/16 in. plate cutting to seat the plate between the tie plate shoulders and about ⅛ in. to fully seat the plate at its ends. These results are considered good for a track on which the traffic consisted of principally high speed passenger and freight trains, slow moving freight trains generally being diverted to one of the outside main tracks.

Tests on 112 RE Rail

This test includes a comparison of two Elastic spikes, two and four cut spikes used as hold-down fastenings in 13-in. tie plates and creosoted gum ties in main track No. 3 which handles northbound traffic consisting largely of freight trains.

Even with the expensive GEO construction, the tie life, by virtue of failure from causes other than mechanical wear, may not be appreciably longer than with standard construction on tangent track having a light or moderate density of traffic.

Report on Assignment 8

Effect of Lubrication in Preventing Frozen Rail Joints

C. W. Breed (chairman, subcommittee), F. J. Bishop, Blair Blowers, H. F. Busch, M. D. Carothers, E. W. Caruthers, R. A. Emerson, H. F. Fifield, W. E. Griffiths, C. T. Jackson, C. H. Johnson, T. R. Klingel, J. de N. Macomb, E. E. Martin, C. E. Price, M. K. Ruppert, R. R. Smith, Troy West.

This is the fourth annual progress report of the rail joint lubrication service tests on the Chicago, Burlington & Quincy Railroad, and is offered as information.

Foreword

This test installation includes five miles of the Burlington's westward main track near Earlville, Ill., in high speed territory. Last year's report was published in the Proceedings, Vol. 50, 1949, page 626. The fourth test period covers the 13⅛-month interval ended August 10, 1949, in which the traffic amounted to 15.7 million gross tons, of which 12.3 million tons were freight. During the 49-month test period the test track carried 68.0 million gross tons. Fig. 1 shows the location plan of the test sections.

Discussion of Test Data

Rail Joint Gap

Figs. 2 to 5 incl., show a summary of the rail gap width measurements for each test section by percentages in the several increments, as was done in previous years. For freezing temperature (Figs. 2 and 3) there was no section that had a superior uniformity of joint gap width. In both rails the average joint gap width was the smallest in the west half of mile 72 with liquid asphalt rail coating. It is possible there is less slippage of the rail in joints with the liquid asphalt because that half-mile stretch of track is in a sag and the rail will not creep uphill to the west against the traffic. For the summer temperatures (Figs. 4 and 5) most of the rail gaps were in the first increment (0.00 in. to 0.04 in.) and in several of the test sections of the south rail with reformed head-contact joint bars, over 90 percent of the joints were in the first increment.

There were no important differences in the uniformity of the joint gap width in the sections with lubrication or those having no lubrication.

An analysis of the change in the joint gap width from summer to winter for each joint indicates a progressive increase in joint slippage resistance as determined from the number of joint gaps in each rail which changed 0.03 in. or less. For the north and south rails, respectively, the percentage of joints in this category for the 5-mile test was 15 and 25 by comparing the summer of 1946 with the winter of 1947, and these figures had respectively increased to 33 and 45 percent for the measurements of the summer of 1948 and the winter of 1949. The rail with the headfree bars had 73 percent as many of these joints as in the rail with head contact bars.

TABLE 3. - SERVICE TEST OF MECHANICAL WEAR OF CREOSOTED GUM TIES WITH THREE ARRANGEMENTS OF ANCHOR SPIKES IN TRACK NO. 3, NORTHBOUND MAIN OF THE ILLINOIS CENTRAL SYSTEM NEAR M.P. C-43, NORTH OF MANTENO, ILL.

New 112-lb RE rail with 6-hole joints laid in 1944, tangent track.

7 3/4 in. by 13 in. by 27/32 in. double shoulder tie plates, flat seat, 1:40 ± cant, wave bottom, tapered shoulder extensions, eccentricity 3/8 in., 15/16 in. dia. holes for anchor spikes. Branded 419.

Number and Kind of Anchor Spikes Per Tie Plate	Number of Test Panels	Tie Plate Penetration in 0.001 in. from August 1945 to July 1949 (90 Million Gross Tons)				
		West Rail		East Rail		Both Rails Average
		End of Tie Plate				
		Field	Gage	Gage	Field	
2 Cut Spikes	1	52	59	71	49	58
4 Cut Spikes	1	51	65	65	67	62
2 Elastic Spikes-No.91	2	55	43	55	39	48

Missouri Pacific Railroad

In 1930 the Missouri Pacific Railroad installed in its single-track main line near Middlebrook, Mo., about 90 miles south of St. Louis, Mo., a stretch of GEO track having 7-in. by 14-in. tie plates with four screw spike plate fastenings and also a stretch of standard track with 8-in. by 10-in. single-shoulder tie plates having two cut spike rail fastenings. The single-shoulder tie plates had ½ in. eccentricity, but in most cases the shoulder was ¼ in. away from the rail base, making the effective eccentricity close to ⅝ in. New 110 RE rail also was laid in both stretches in 1930.

Tie plate penetration measurements were made by the research staff in March 1949 by taking readings from the top of the tie plates to the original adzed surface on 10 consecutive creosoted oak ties (placed in 1930) for each type of construction and also on 10 oak ties placed in 1935 with the single-shoulder tie plates. The plate cutting was then determined from the plan thickness of the tie plate shoulder extensions. It is realized that tie plate thickness is not constant but the data presented below will give a reasonably good comparison of the average plate cutting.

Creosoted Oak Ties in Tangent Track	*Penetration in in.* *Field End*	*Gage End*	*Average*	*Traffic in Million Gross Tons*
GEO—7 by 14 in. (1930)	0.18	0.19	0.185	236
Standard—8 by 10 in. (1930)	0.16	0.56	0.36	236
Standard—8 by 10 in. (1935)	0.13	0.42	0.275	...

It will be observed that the plate cutting at the ends of the GEO tie plates was about equal, while with the 8-in. by 10-in. plates the cutting at the gage end was much greater than at the field end, which results in fairly tight gage. The average penetration for GEO construction was about half that for the standard construction which had 18 percent less plate area.

It has only been necessary to renew a few of the GEO ties. Occasionally, however, a plate has cut into the tie as much as one inch or more. Most of the ties are quite badly split and checked and it does not appear that they will last many years longer, even though the amount of plate cutting is moderate.

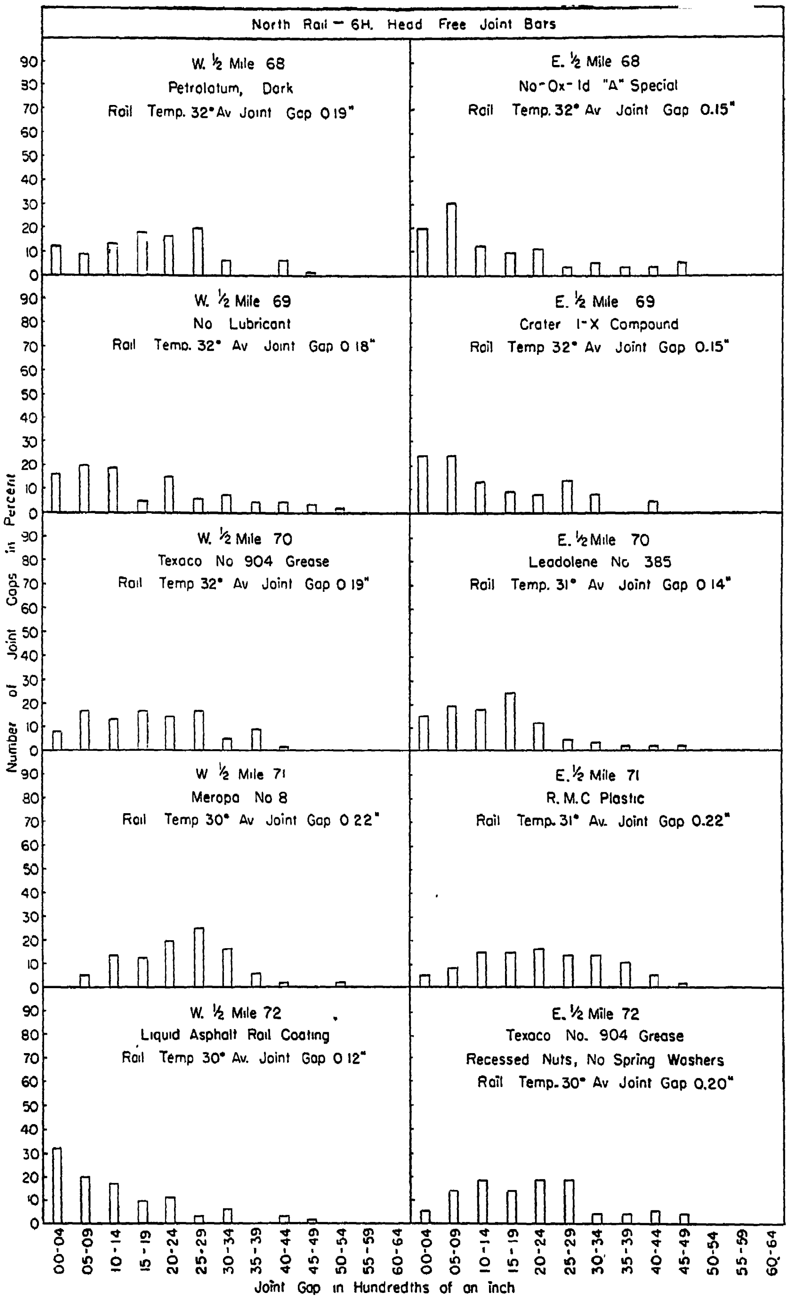


Fig. 2. Joint Gap Measurements for Rail Joint Lubrication Test March 9, 1949
C.B.&Q.R.R Leland to Earlville, Ill.

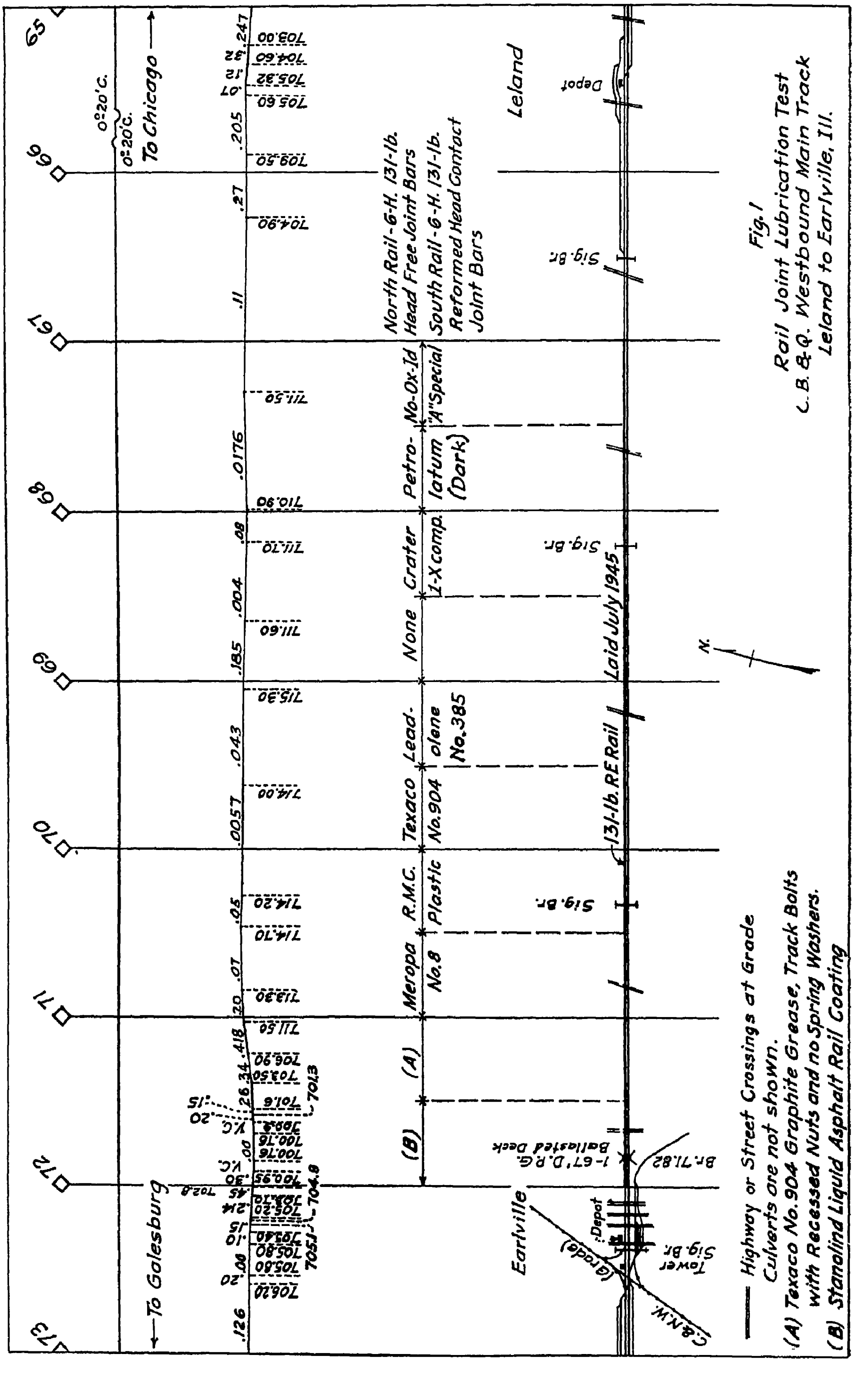


Fig. 1
Rail Joint Lubrication Test
C. B. & Q. Westbound Main Track
Leland to Earlville, Ill.

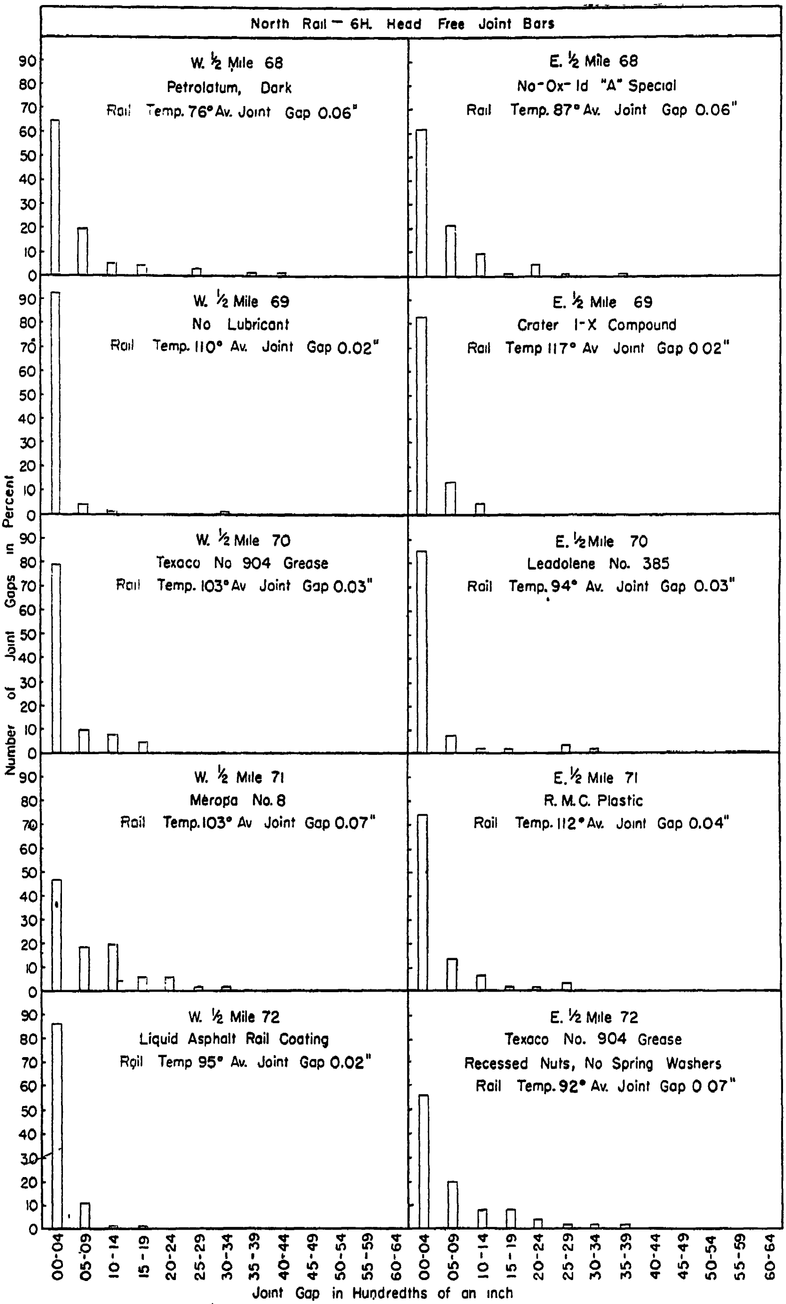


Fig. 4. Joint Gap Measurements for Rail Joint Lubrication Test July 27, 1949
C.B & Q.R.R. Leland to Earlville, Ill.

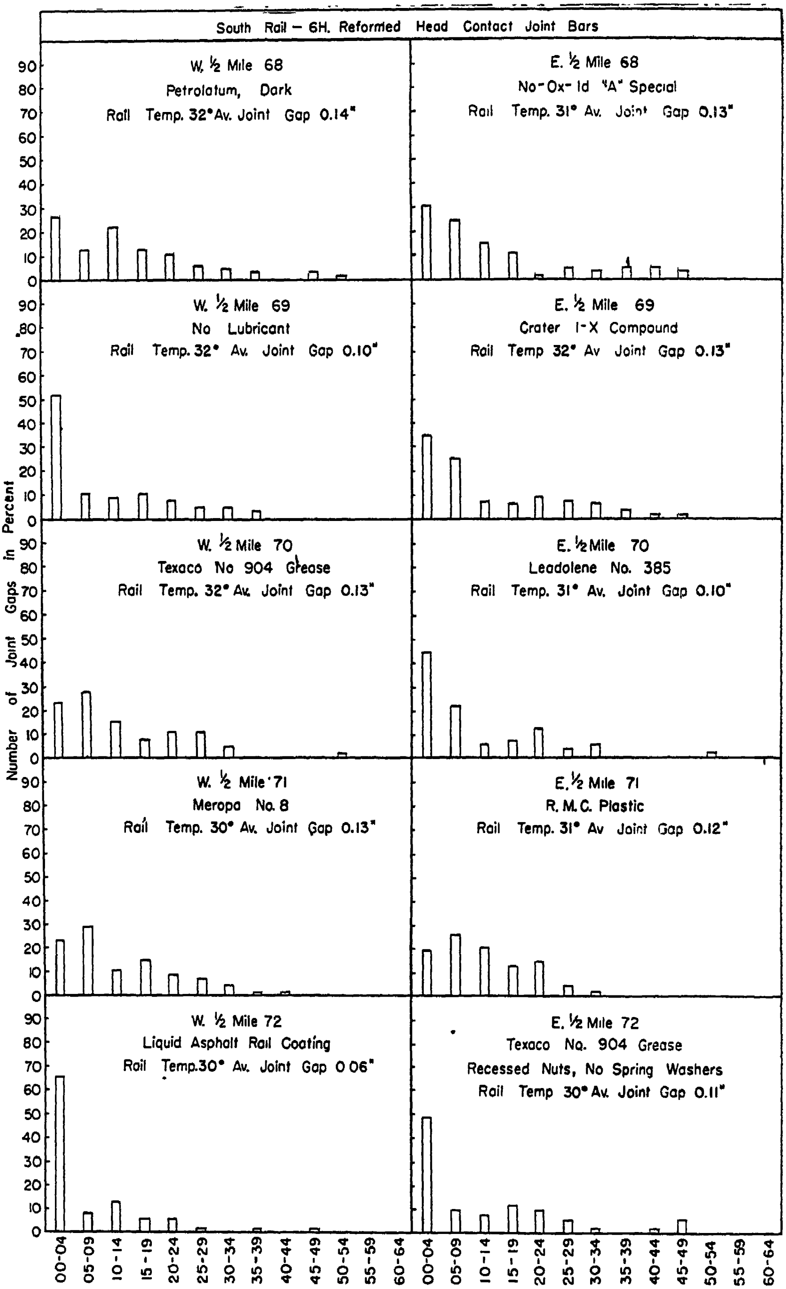


Fig. 3. Joint Gap Measurements for Rail Joint Lubrication Test March 9, 1949
C.B.&Q.R.R. Leland to Earlville, Ill.

Joint Bar Pull-In

These data are based on measurements taken on all of the joints in each test section, the same as in the case of the rail gaps, and are shown in Fig. 6 for the four-year test period. In both rails except in the sections having the RMC joint packing there are no significant differences in the amount of pull-in or joint wear for the total test period. The curves for the RMC sections continued to ascend on about the same slope as for the third service period.

The average pull-in for the 10 sections in the north rail with headfree bars for the four-year test period ranged from 0.039 to 0.076 in., and the corresponding figures for the south rail with reformed head contact bars varied from 0.067 in. to 0.103 in. The overall average pull-in for the north and south rails of the five-mile stretch of track was 0.048 in. and 0.079 in. respectively. This seems to be a reasonable comparison for the two types of joints. So far, the several lubricants have not been effective in reducing joint wear. The pull-in of the sections without lubrication was appreciably less than that of the corresponding sections with the RMC packing.

Bolt Tension

Bolt tension measurements have been taken each summer on 90 bolts of the middle 15 joints of each half mile of rail. These data are presented in graphical form for the four test periods in Fig. 7. The average bolt tension applied and remaining at the end of each test period, as well as the percentage loss in tension is indicated in the figure. For the last service period the average applied tension in the 1-in. track bolts for the test sections in the north rail with headfree bars varied from 18,200 lb. to 22,500 lb., and the corresponding figures for the south rail with reformed head contact bars were 18,500 lb. to 20,100 lb., resulting in an average for the north and south rail of 20,400 lb. and 19,300 lb., respectively. In each rail the highest percentage loss in bolt tension for the last period occurred in the section with the liquid asphalt rail coating, whereas in the third year, the no-lubricant section in each rail showed the greatest loss in percentage. In the north rail, sections with Leadolene, Crater 1–X compound and Texaco No. 904 grease (standard construction) had the lowest percentages, while in the south rail the above first and last mentioned sections were lowest. The average loss in bolt tension for entire north and south test rails, respectively was 43 and 44 percent. The fact that headfree joint bars pull in less than head contact joint bars has not been beneficial in sustaining a higher percentage of bolt tension.

From the bolt tension measurements in 15 joints of each test section, Table 1 has been prepared to show the percentage of bolts having less than 5000 lb. tension at the end of the fourth test period. In the 5-mile stretch of track there were 6 and 12 percent of bolts in this category for the south and north rails, respectively. The highest percentage of bolts with insufficient remaining tension in the north rail was in the sections with Crater 1–X compound and Texaco No. 904 grease without spring washers, and for the north rail, those sections with liquid asphalt rail coating and the section without spring washers were the highest. A bolt tension of 5000 lb. is considered the minimum required for the proper functioning of the symmetrical type of bars.

Maintenance of Way Report

For each service period the roadway forces of the Burlington maintain a record of the number of loose and broken bolts and stripped joints for each of the 20 test sections. In 1945 at the beginning of this test, a loose bolt was defined as one that would shake in its hole, or that had worked out of place, as this would simplify the reporting and

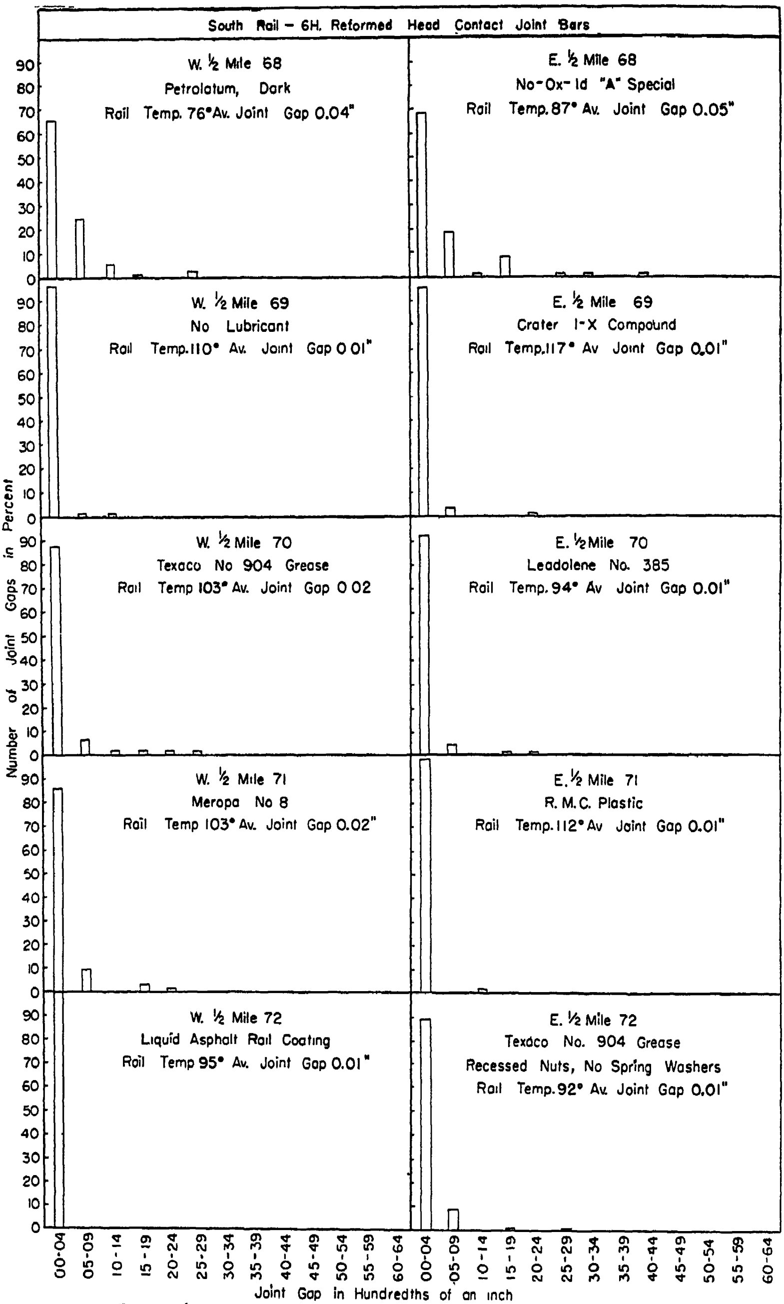
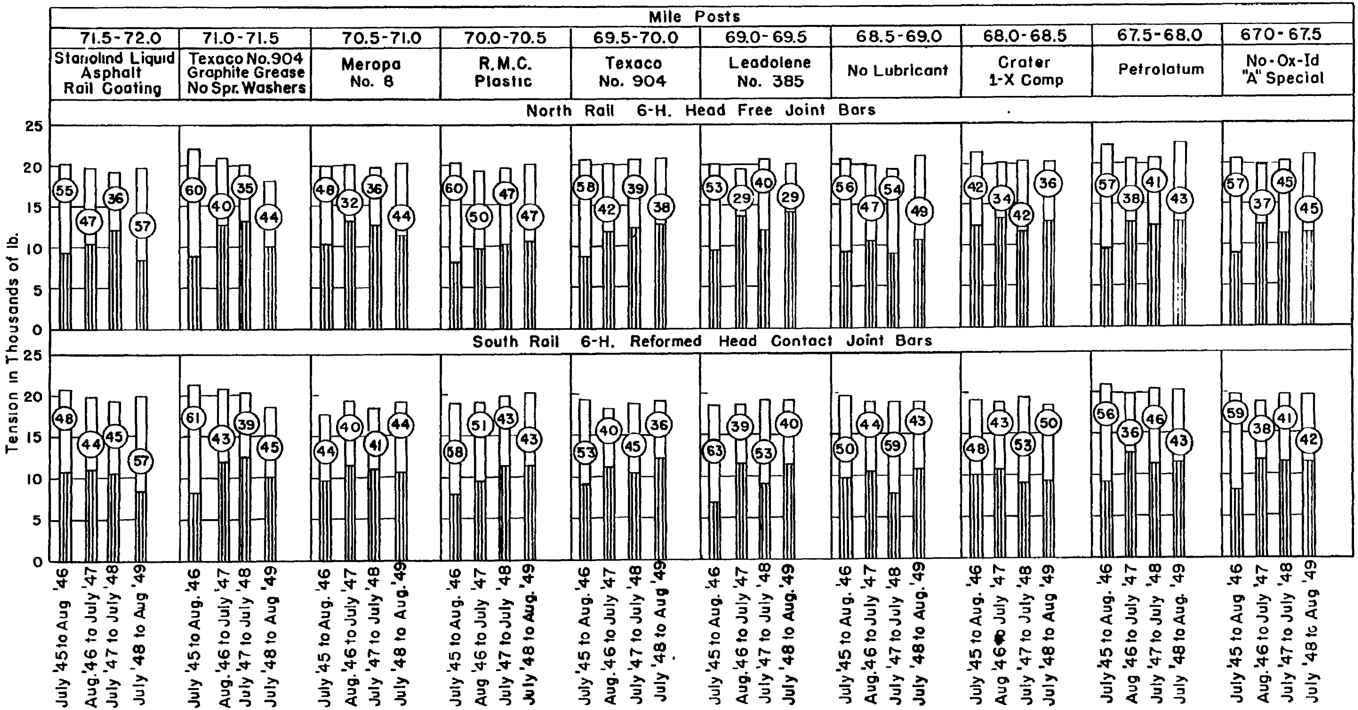
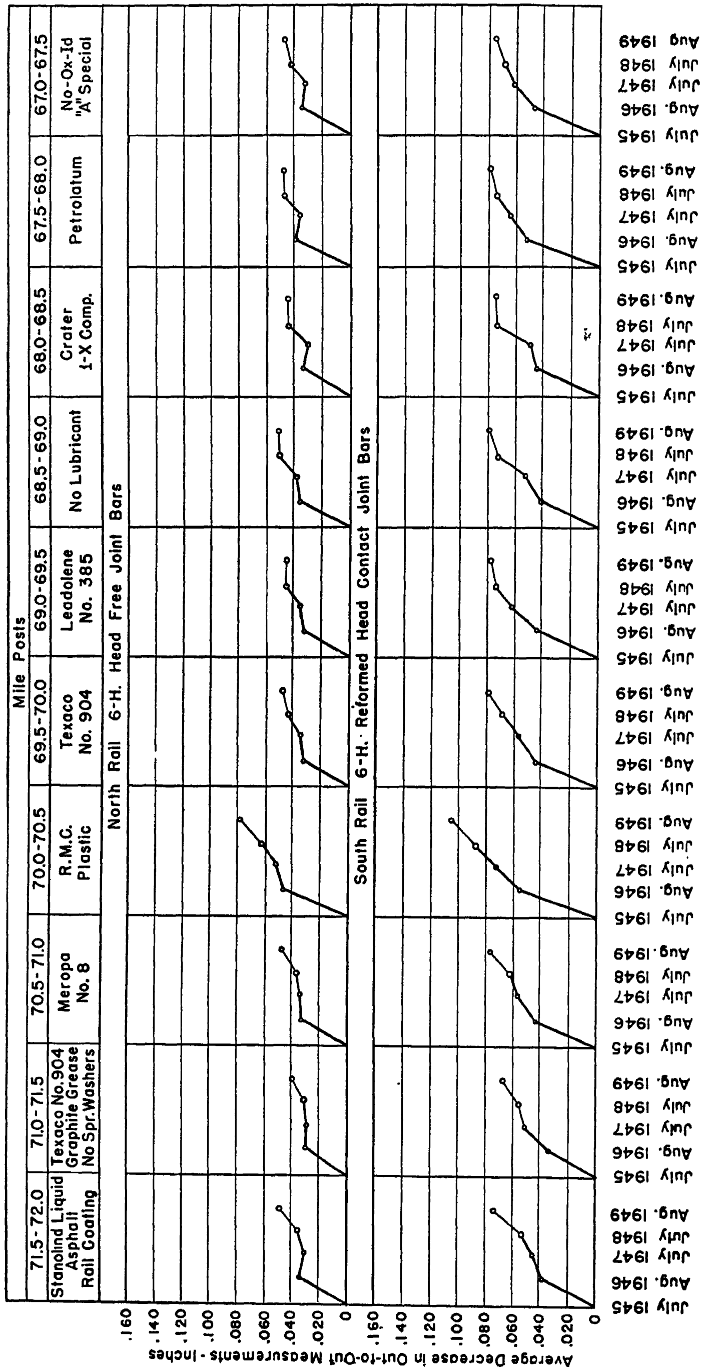


Fig. 5. Joint Gap Measurements for Rail Joint Lubrication Test July 27, 1949
C.B.&Q.R.R. Leland to Earlville, Ill.



Note: Top of columns shows Average Tension in 15 joints at the beginning of Test periods
Top of Shaded Part of columns shows Remaining Tension at the end of Test periods.
Figures in circles indicate Percent of Tension Lost.

Fig. 7.—Bolt Tension, C. B. & Q. R. R., Leland to Earlville, Ill.



Note: Out-to-out measurements taken at top and bottom of ends and middle of all joint bars. Values shown are the mean of top and bottom of bars.

Fig. 6.—Average Pull-in of Joint Bars, C. B. & Q. R. R., Leland to Earlville, Ill.

TABLE 2. SERVICE REPORT OF LOOSE AND BROKEN BOLTS *
C. B. & Q. RR. RAIL JOINT LUBRICATION TEST, M. P. 67 TO M. P. 72, W. B. MAIN
JULY 1, 1948 TO AUGUST 10, 1949

South Rail						North Rail		
H.C. Joints						H.F. Joints		
No. of Bolts						No. of Bolts		
Loose	Broken	Total	M.P. to	M.P.	Lubricant	Loose	Broken	Total
0	0	0	67	67½	No- Ox- Id "A" Special	0	1	1
0	0	0	67½	68	Petrolatum (Dark)	1	0	1
0	0	0	68	68½	Crater 1-x Compound	1	0	1
0	0	0	68½	69	No Lubricant	0	0	0
0	0	0	69	69½	Leadolene No. 385	0	5(a)	5
0	0	0	69½	70	Texaco No. 904 Grease	0	0	0
0	0	0	70	70½	R.M.C. Plastic Packing	0	1	1
0	0	0	70½	71	Meropa No. 8	0	1	1
5	0	5	71	71½	Texaco No. 904, Recessed Nuts, No spring washers	4	0	4
0	0	0	71½	72	Liquid Asphalt Rail Coating	0	0	0
5	0	5	Totals			6	8	14

* Also includes loose bolts (shown in Table 1) found by AAR Research Staff when checking bolt tension in August, 1949.

(a) Includes one stripped joint.

There was little lubrication left on the top fishings of the bars except in the sections with Petrolatum (dark), No-Ox-Id "A" special and Leadolene No. 385, where from 25 to 60 percent of the surface was lubricated. The extent of lubrication observed on the lower fishings was greatest in the sections with RMC joint packing, Petrolatum (dark), No-Ox-Id "A" special and Leadolene No. 385, ranking in the order listed. In Figs. 8 to 16, incl., the condition of the lubricants may be observed. In these figures the upper views show the rail and the top of the bars and the lower views, the bottom fishing of the bars. Most of the traffic is westbound, or to the left of the photographs.

The rating of the various lubricants as to weather resisting properties is the same as given last year; RMC packing, No-Ox-Id "A" special and Petrolatum being the best, Leadolene second and the others being in the poorest group.

Only five bolts had battered threads, and after backing off the nuts the bolt threads were lubricated except in the section without a lubricant. End plugs seem to be very desirable for keeping out the debris, brine, sand and water, to reduce corrosion and to extend the life of the brushed-on lubricant, and possibly the joint bars. In sections where the lubricant had become dry or weathered away, hard layers of rust had formed in the lower rail fillet along approximately three inches of the ends of the joint bars, especially at the receiving end, and this condition can possibly reduce the service life of the joint bars by preventing the use of all of the take-up provided in the design of joint.

Solvated Sealz Joint Packing

As described in last year's report, six joints with head contact bars in the no lubricant section were packed with Solvated Sealz slabs, consisting of reclaim rubber and

TABLE 1. PERCENTAGE OF BOLTS IN 15 JOINTS OF EACH TEST STRETCH WITH BOLT TENSION LESS THAN 5,000 LB. FOUND AT THE END OF THE FOURTH TEST PERIOD AFTER 13 1/3 MONTHS TRAFFIC

South Rail H.C. Joints Percent	M.P. to M.P.	Lubricant	North Rail H.F. Joints Percent
3	67 67½	No- Ox- Id "A" Special	11
3	67½ 68	Petrolatum (Dark)	9 (a)
12	68 68½	Crater 1-x Compound	12 (a)
8	68½ 69	No Lubricant	13
5	69 69½	Leadolene No. 385	4
5	69½ 70	Texaco No. 904 Grease	7
2	70 70½	R.M.C. Plastic Packing	9
5	70½ 71	Meropa No. 8	9
10 (b)	71 71½	Texaco No. 904, Recessed nuts, no spring washers	20 (a)
9	71½ 72	Liquid Asphalt Rail coating	28
6		Average	12

(a) Includes one loose bolt.
(b) Includes three loose bolts.

avoid the inclusion of bolts retightened because, in the judgment of the track man, they had insufficient tension. In last year's report, through a misunderstanding, an appreciable number of bolts were reported, particularly for the north rail with headfree bars, that had been retightened because of having insufficient tension instead of actually being loose.

Table 2 is presented to show the loose and broken bolts for the fourth test period and includes only the loose bolts that were so classified for the purpose of this test. The south rail with reformed head contact joint bars continued to make the best showing with only five loose bolts with none broken in the five miles of rail, while in the north rail, there were six loose bolts and eight broken ones, and one joint pulled in two. Most of the loose bolts occurred in the section with recessed nuts and no spring washers and a majority of the broken bolts were found in the north rail section with Leadolene.

Inspection of Dismantled Joints

Original Test Installation

The fourth annual inspection was made in September 1949 and was witnessed by three railroad representatives in behalf of two subcommittee members, five representatives of three manufacturers and H. E. Durham of the research staff. The subcommittee chairman was unable to attend because of a recent illness.

Sixteen dismantled joints with head contact bars were inspected and photographed. In connection with the application of a new type of packing, which will be described later, six head contact joints were dismantled and inspected in the no-lubricant section, but not photographed. Each year the joints selected for this inspection are those that had not been previously used for this purpose.

Fig. 10.—Crater 1-X Compound.

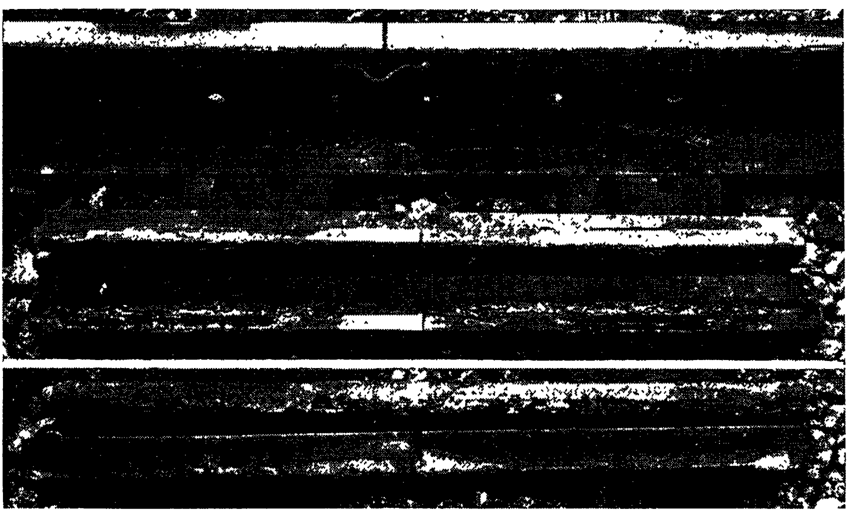


Fig. 11.—Leadolene No. 385.

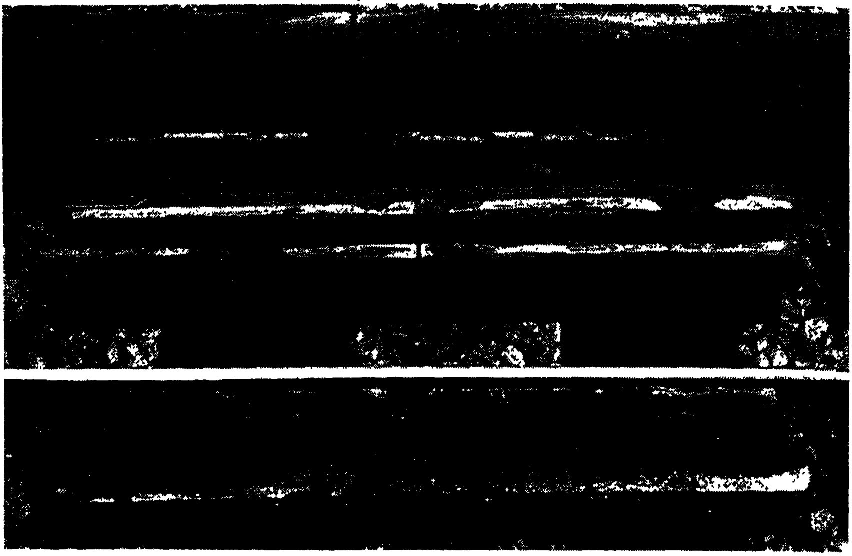


Fig. 8.—No-Ox-Id "A" Special.

Fig. 9.—Petrolatum (Dark).

Fig. 14.—Meropa No. 8.

Fig. 15.—Texaco 904 Graphite Grease (Recessed Nuts, No Spring Washers).

Fig. 12.—Texaco 904 Graphite Grease (Standard Construction).

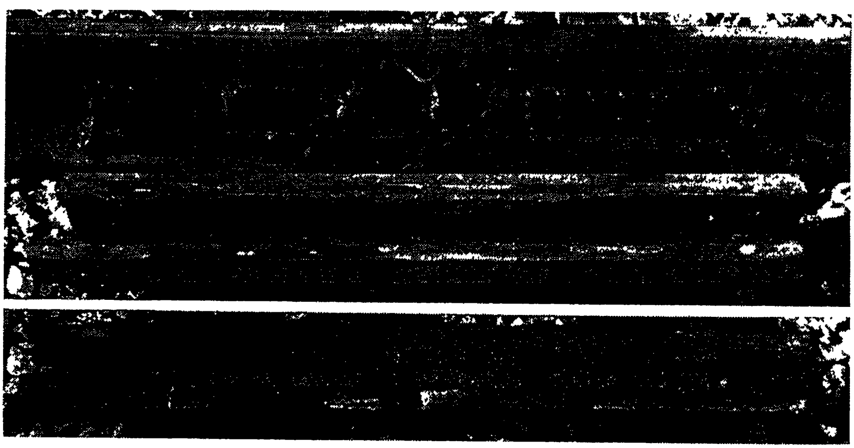


Fig. 13.—R. M. C. Plastic Joint Packing.

Application of Lime Soap Grease—Graphite Slabs

The Esso Standard Oil Company has developed a block grease, known as 3208 rust preventive, for packing rail joints. It is a specially compounded lime soap grease with a melting point of approximately 215 deg. F. and contains graphite. It has an unworked penetration at 77 deg. F. of about 40, which was not too hard for convenient application in the field in mild weather. The slabs were furnished in 12-in. lengths, wrapped in wax paper and were applied to six joints with head contact bars in the no-lubricant section near M. P. 69. The bars and rail ends were cleaned with a wire brush before placing the grease slabs. The liberal cross section of 1¼ in. by 3½ in. for the slabs was quite effective in causing the material to squeeze out and over the fishing surfaces.

About 12 lb. of material was used in each joint, although 10 lb. should be ample.

Conclusions

This four-year service test has developed that RMC joint packing, No-Ox-Id "A" special and Petrolatum (dark) had superior weather resisting properties. No type of lubricant, as yet, seems to be superior in effecting a significant reduction in joint wear, or pull-in. The RMC packing definitely showed a relatively large pull-in and this may have been influenced by its deficiency on the upper fishings.

Only one joint has pulled in two and that occurred during the fourth test period in the north rail with headfree bars and Leadolene No. 385. In view of this, as well as the fact that the section without lubrication has had no stripped joints, there is no supporting evidence for appraising the several lubricants as to their relative effectiveness in the prevention of frozen joints and "pull in twos."

No type of lubricant has demonstrated any significant advantage for promoting uniformity of the joint gap width. However, it is probable that other factors, such as rail anchorage, the variations in the fit of the joint bars and the rail and bolt tension, causing a wide scatter in joint slippage resistance, may make it impossible in conventional track to obtain a good uniformity of joint gap width.

Even if some of the lubricants have weathered badly, it seems necessary to continue this test for another year or two in order to develop more information on joint bar pull-in, broken bolts and stripped joints.

Acknowledgment

The committee and the Association are indebted to the Burlington for its cooperation and assistance in conducting these tests.

Report on Assignment 9

Rail Anchorage for Various Conditions

E. E. Martin (chairman, subcommittee), L. L. Adams, J. C. Aker, A. L. Bartlett, T. H. Beebe, F. J. Bishop, H. J. Bogardus, A. E. Botts, M. D. Carothers, E. W. Caruthers, W. E. Cornell, H. F. Fifield, J. W. Fulmer, A. B. Hillman, J. P. Hiltz, A. F. Huber, H. F. Kimball, T. R. Klingel, S. H. Poore, M. K. Ruppert, R. R. Smith, Troy West.

Your committee submits the following progress report as information.

During August and September 1949 members of the research staff, with the cooperation of the Chicago, Milwaukee, St. Paul & Pacific Railroad, conducted a test with strain measuring equipment on the single track line of that railroad near Kansasville, Wis. Rail creepage forces transmitted to the ties by the rail anchors were measured under

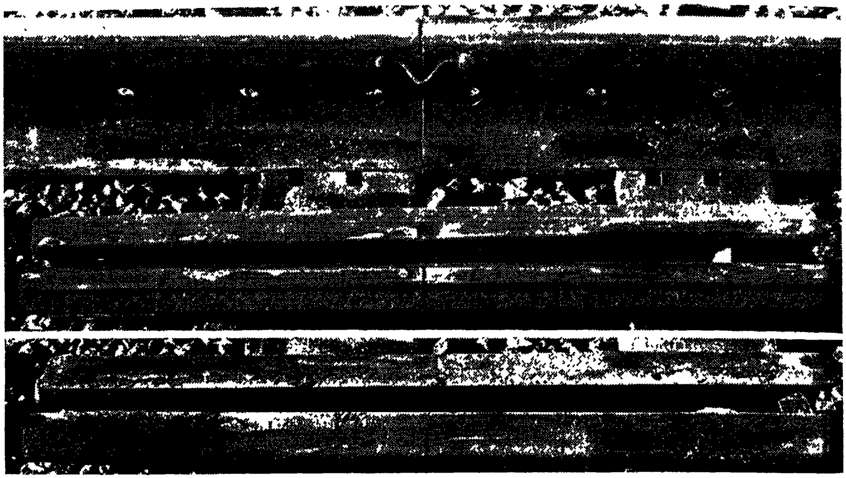


Fig. 16.—Liquid Asphalt Rail Coating.

natural and synthetic resins. The photographs shown in Fig. 17 were taken after approximately one year of traffic. Only the gage bar was removed for the inspection and westward traffic is to the right. The bond of this material with the rail web and joint bars was so effective that the material pulled apart except for a small area where no new corrosion was present. No moisture or water pockets were present. In Fig. 17 the bolt shanks (but not the threads) were thoroughly coated with the packing. Also the material squeezed through and across most of the fishing surfaces.

As previously mentioned, Solvated Sealz has no lubricating property but will seal out the weather, etc. It was difficult and expensive to apply.

Fig. 17.—Solvated Sealz Joint Packing.

Report of Committee 1—Roadway and Ballast

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W. L. YOUNG

Committee

* Died February 9, 1949.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

Bulletin 486, February 1950.

two-directional traffic with special weigh bars attached to the ties for four arrangements of the weigh bars. Longitudinal movement of the rails was also recorded on the oscillograms. Three static tests were also made by breaking the track and jacking the rails for different plans of anchorage to determine the forces required to move ties in gravel ballast with the track unloaded. A continuous record of the rail movement with Ames dials was maintained throughout the four dynamic test series. Temperature stresses in the rails were measured during one of the dynamic tests.

A report of the results obtained will be presented in the committee report next year.

Pages 1–6.1 to 1–6.6, incl.

I PHYSICAL PROPERTIES OF EARTH MATERIALS

1938

101. GENERAL

102. PHYSICS OF SOILS

A. SOIL GENESIS

B. PHYSICAL PROPERTIES

C. CLASSIFICATION OF SOILS

103. ROADBED

A. BEHAVIOR

Submitted for reapproval without change.

Pages 1–6.7 to 1–6.8, incl.

II NATURAL WATERWAYS

1938

201. GENERAL

202. DRAINAGE AREAS AND WATER RUN-OFF

Submitted for reapproval without change.

Pages 1–12.01 to 1–12.04, incl.

III CULVERTS

1939

301. LOCATION AND TYPE

A. WATERWAY REQUIRED

B. SPAN REQUIRED

C. CHARACTER OF HYDRAULIC TRAFFIC (ABRASIVE, CORROSIVE, ETC.)

D. TOPOGRAPHIC CONDITIONS DETERMINING ANGLE, GRADIENT, AND LENGTH OF STRUCTURE

E. FOUNDATION CONDITIONS

F. HEIGHT AND CHARACTER OF EMBANKMENT

G. LOADING, LIVE AND DEAD

H. ECONOMICS OF VARIOUS TYPES

Submitted for reapproval without change.

Pages 1–36.1 to 1–40, incl.

403. INFORMATION

D. ECONOMICS OF FILLING BRIDGE OPENINGS

(1926, 1936)

Submitted for reapproval without change.

5. Roadway drainage: Critical review of recommended practice.
   No report.

6. Roadway: Formation and protection:
   (a) Roadbed stabilization.
      Progress report, presented as information .... page 727
   Fifth progress report on investigation of roadbed stabilization .... page 728
   (b) Construction and protection of roadbed across reservoir areas; specifications.
      Progress report, presented as information .... page 755
   (c) Chemical eradication of vegetation.
      No report.

7. Tunnels: Construction and maintenance.
   No report.

8. Fences:
   (a) Corrosion-resisting fence wire, collaborating with Committee A-5 on Corrosion of Iron and Steel, ASTM.
      No report.
   (b) Electric shock fences and their adaptability to railroad requirements, collaborating with the Electrical Section, Engineering Division, AAR.
      No report.
   (c) Instructions for maintenance inspection of fences.
      No report.

9. Signs.
   No report.

10. Ballast:
   (a) Tests.
      No report.
   (b) Ballasting practices.
      No report.
   (c) Special types of ballast.
      No report.

THE COMMITTEE ON ROADWAY AND BALLAST,
H. W. LEGRO, *Chairman.*

Report on Assignment 1

Revision of Manual

A. P. Crosley (chairman, subcommittee), F. W. Biltz, L. H. Bond, B. H. Crosland, J. W. Demcoe, A. T. Goldbeck. L. V. Johnson, Paul McKay, J. A. Noble, A. W. Schroeder.

Your committee has made a study of its chapter in the Manual and recommends the following changes:

Part I. Soil Pressure Cells

Introduction

This is the second progress report on subgrade pressures from normal traffic as registered by soil pressure cells under the Burlington track near Red Oak, Iowa. The work was conducted with committee sponsorship under the general direction of G. M. Magee, research engineer of the Engineering Division, AAR, by Rockwell Smith, roadway engineer, and M. F. Smucker, assistant electrical engineer, of the research staff.

The description of the 1948 tests appears in the Proceedings, Vol. 50, 1949, pages 651–656. The set-up for the work in 1949 was identical with that described in Vol. 50. Eleven additional runs were recorded so that the data discussed in this report consist of a series of test runs prior to and two series subsequent to grouting with an interval of 10 months between the latter.

It was discovered during the 1949 tests that the electrical circuits for the pressure cells were becoming uncertain, and while no apparent results affecting the reliability of the 1949 data were disclosed, it was felt that another year of exposure in the roadbed would probably cause the circuits to short out. Consequently, the cells were removed shortly after the 1949 tests. Future installations will have additional insulation to preserve the circuits for long-time tests if desired. Calibration of the cells after removal from the roadbed showed the cells, with the exception of No. 5, were fully operative, and except for resistance of the circuits gave factors nearly identical with the original calibration within the range of pressures recorded. Cell No. 5 became inoperative before the first series of tests in 1948. On removal from the roadbed it was found to be full of water.

Discussion

The data from 20 representative runs are presented in Table 1. The axle loads shown in column 2 are the approximate average of the load on one pair of steam locomotive drivers and on one pair locomotive wheels of diesel. Column 3 shows the sum of the tie loads. These loads were measured by strain gages recording bending stresses on the bottom of the tie plates on five ties, two either side of the line of pressure cells and one directly over the cells. The rail was shimmed off the tie plate and the tie plate off the tie to concentrate the loads. Fig. 1 shows the layout. The loads under one rail only were so recorded. Therefore, the tie load was taken as double the measured load and in the theoretical computations this total load was assumed to be distributed uniformly over the bottom of the tie. All ties were considered as having 6 in. by 8½ in. by 8 ft. dimensions. Using these measurements and the recorded tie loads, the theoretical pressure at each pressure cell was computed by the use of Newmark's charts. (Influence Charts for Computation of Stresses in Elastic Foundations, Nathan M. Newmark, Bulletin Series No. 338, University of Illinois Engineering Experiment Station.) These pressures were integrated graphically for the 14-ft. width covered by the pressure cells and the average value over that width recorded in column 4 as the equivalent pressure. For the depth of the pressure cell installation, it is estimated that the 14-ft. width will account for approximately 98 percent of the theoretical vertical pressure reaction and that the pressure intensity 9 ft. out from center line will amount to less than 1 percent of the pressure intensity at the bottom of the ties, decreasing quickly with additional width.

The assumption of uniform spread of the tie loads over the bottom of the tie and thus into the ballast was made for lack of definite information as to the prevailing conditions. There is good reason to believe, and previous experimental data to substantiate, that this is not the case, but few data are available to indicate the actual

Pages 1–66.1 to 1–66.4, incl.

VII TUNNELS

1938

701. ALINEMENT AND GRADE

702. SPECIFICATIONS FOR CONSTRUCTION, EXCAVATION AND TEMPORARY LINING OF TUNNELS

703. VENTILATION

704. LIGHTING

Submitted for reapproval without change.

Pages 2–16.1 to 2–22, incl.

BALLAST

BALLAST SECTIONS FOR SINGLE AND MULTIPLE TRACK ON TANGENT AND CURVES

(1938)

Submitted for reapproval without change.

Report on Assignment 2 (a)

Physical Properties of Earth Materials

Roadbed. Load Capacity. Relation to Ballast. Allowable Pressure

J. W. Demcoe (chairman, subcommittee), J. P. Datesman, J. G. Gilley, L. H. Jentoft, W. T. Johnston, J. W. Poulter.

This is the second progress report on the study of soils being conducted by the Engineering Division, AAR, research staff. It consists of two parts. Part I continues the report first made last year on soil pressure cells installed in the tracks of the Chicago, Burlington & Quincy Railroad near Red Oak, Iowa. Part II is the first report on the investigation of unstable railroad fills by means of exploratory borings and laboratory tests. These tests were devised to determine conditions prevailing and to evaluate soil strengths in fills that have a record of high maintenance costs. It was suggested in last year's report of this subcommittee that these tests would be on the basis of cone penetrometer and oscillator tests. The penetrometer method was abandoned in favor of borings and thin tube samples for laboratory analyses. The oscillator tests could not be made because of a reduction in the funds available to the Engineering Division for research. Laboratory tests with an oscillator which are also related to the assignment of this committee are reported as Part III of the report on roadbed stabilization, subcommittee 6 (a).

These reports are recommended for study. They serve to indicate the various considerations involved in the analysis of an earth structure and give promise that further research will yield information of great value. It is the opinion of the subcommittee that too little attention has been given to a fundamental problem of railway maintenance—load capacity and allowable pressures on subgrades.

Greater Effects Recorded for Steam Locomotives

Steam power produced higher tie loads than the axle loads would indicate, and as a result the subgrade pressures both theoretical and recorded are above those for diesel power in greater proportion than the increase in axle loads. This probably is due to the impact features of steam power. Also the ratios of recorded to theoretical pressures are generally greater for steam for the few runs obtained. This factor is probably the result of the vibration effects of impact, and the oscillograph records indicate appreciably more vibration under steam power. Speed effect could not be differentiated under the runs obtained.

The data in columns 3, 4 and 5 are plotted in Fig. 2 with the total load on the five ties as ordinates and the soil pressures as abscissae. There is very good straight line correlation between the total load and the theoretical pressures; also between the load and the recorded pressures prior to grouting. The lines for the two cases indicate that the pressure cells are registering proportionally. Variations of the points for the theoretical pressures, from the plotted line occur because the distribution and proportion of the total tie load carried by each tie differed for different runs. The close general agreement, however, indicates that this method of analysis to check the action of the pressure cells is sufficiently accurate for its purpose. This graph indicates that prior to grouting the pressure cells are consistently under-registering vertical pressures by about 34 percent.

This apparent under-registration for vertical pressures is not in accord with the measuremnts of horizontal pressures which are in fairly close agreement with the theoretical. This phase will be discussed later, but it indicates that some influence is affecting the full measurement of vertical pressures on the cells.

Two explanations may be considered. The first is possible arching across the trench whereby the vertical pressure is transmitted over the cells to the sides of the trench.

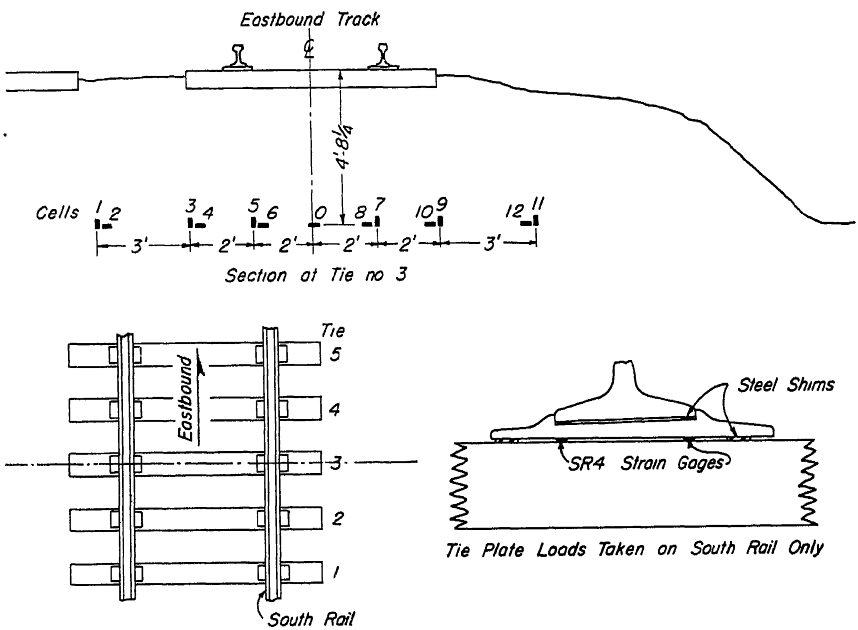


Fig. 1.—General Layout of Pressure Cell Installation.

TABLE 1.—TABULATION OF DATA

Column 1 Run	2 Loco. Axle Load	3 Tie Loads	4 Pressures Psi Theoretical	5 Recorded	6 Ratio of Recorded to Theoretical Pressures	7 Type of Power	8 Approx. Speed mph.
			1948 Prior to Grouting				
16	70,000	53,630	2.25	1.82	0.81	Steam	41
20	70,000	49,620	2.11	1.61	0.76	"	24
19	63,000	36,770	1.45	1.03	0.71	Diesel	44
18	63,000	38,630	1.56	1.13	0.72	"	36
21	53,000	42,100	1.63	1.11	0.68	"	45
22	53,000	44,050	1.75	1.23	0.70	"	45
Avg.	70,000	51,620	2.18	1.72	0.78	Steam	
Avg.	58,000	40,390	1.60	1.12	0.70	Diesel	
			1948 After Grouting				
29	70,000	50,720	2.17	1.16	0.53	Steam	37
30	70,000	57,400	2.47	1.11	0.45	"	38
25	61,000	39,270	1.67	0.84	0.50	Diesel	37
27	54,000	38,880	1.65	0.89	0.54	"	45
28	63,000	35,880	1.45	0.76	0.53	"	37
31	63,000	42,630	1.82	0.70	0.38	"	47
Avg.	70,000	54,060	2.32	1.14	0.49	Steam	
Avg.	60,000	39,160	1.65	0.80	0.49	Diesel	
			1949 9 Months After Grouting				
9	70,000	69,360	3.14	2.84	0.90	Steam	32
4	63,000	48,140	2.09	1.54	0.74	Diesel	45
5	63,000	49,460	2.11	1.41	0.67	"	41
6	62,000	51,750	2.25	1.59	0.70	"	51
7	63,000	45,840	1.94	1.58	0.81	"	44
8	----------	24,530	1.07	0.67	0.63	*	20
10	63,000	47,210	2.05	1.37	0.67	Diesel	44
11	55,000	51,570	2.17	1.59	0.73	"	44
Avg.	61,500	45,500	1.95	1.39	0.71	Diesel	

*Diesel switcher.

pressure pattern. There is also doubt that such a pattern exists or remains constant even for one tie. The assumption of uniform tie pressure appears reasonable for the purpose of this investigation. These pressures were used to compute soil pressures to investigate the relationship of load to pressure as recorded by the soil pressure cells. Furthermore, an assumption of nonuniform tie pressure distribution would have greatly complicated the computations. From the data established by this investigation it now appears that by reversing the computations and using actual recorded pressures a general idea of the tie load distribution can be obtained. This is not in the scope of the present work and will not be reported. It is interesting, however, and will be further investigated.

The theoretical computations of pressure are further based on the assumption that the soil or ballast is a perfectly elastic material, homogenous and isotropic. This is hardly the case for the condition in question, but the theory has been accepted as giving fairly consistent results for vertical pressures on horizontal planes, where the load is known.

Column 5 in Table 1 gives the equivalent uniform pressure over the 14-ft. width as determined from actual pressure cell records. These in all cases are less than the equivalent theoretical pressures, but the ratio of the two remains fairly consistent for each series. There is considerable variation between the series, however, and this phase will be discussed later in the report. The ratios of recorded to theoretical equivalent pressures are given in column 6, Table 1.

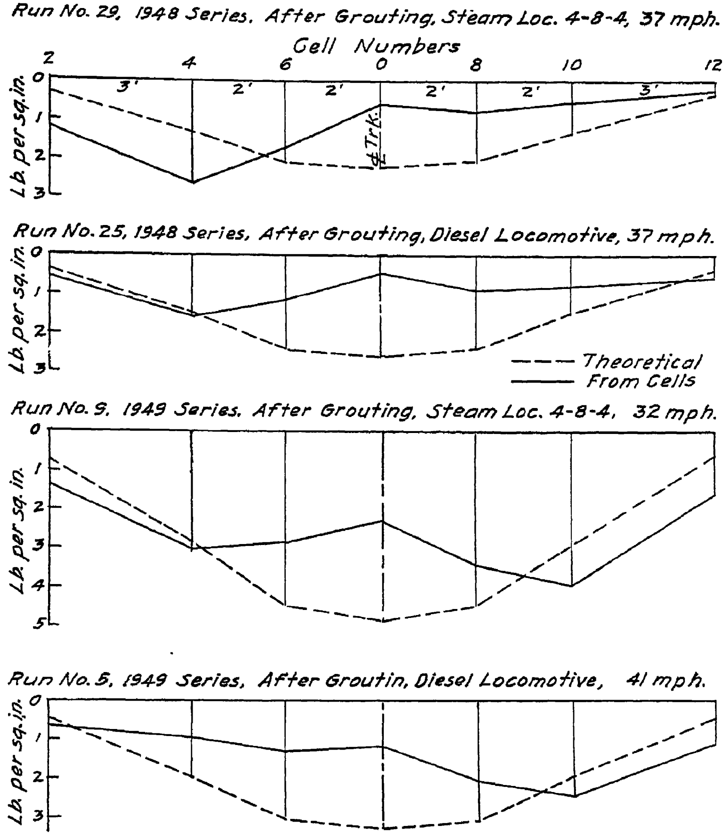


Fig. 4.—Vertical Pressure Distribution Top of Clay Subgrade, 56 in. Below Top of Tie on Section Through Tie No. 3.

This is very possible in the light of previous experiments. The trench as excavated for the placement of the cells was only 2½ to 3 ft. wide. The second possibility is the wider spread of the load in actual loading than is accounted for by the theory. There is some slight evidence of this in the pressure recorded by one cell on the passage of a locomotive on the opposing track. In this case the cell was 19.5 ft. removed from the center line of the loaded track. Theoretical calculation for this point would show only a minute pressure intensity. Of the two possibilities, present knowledge would indicate the first as being the more determining factor.

Theoretical and Recorded Pressures Compared

In Fig. 3 the theoretical and recorded pressures are plotted at the section through the pressure cells for two typical runs. It is to be noted that the recorded pressure is greater than the theoretical under at least one end of the tie and usually is greater at the outside cell positions. The shape of these pressure diagrams indicates a distributed load under the ends of the tie greater than the average pressure over the full tie area.

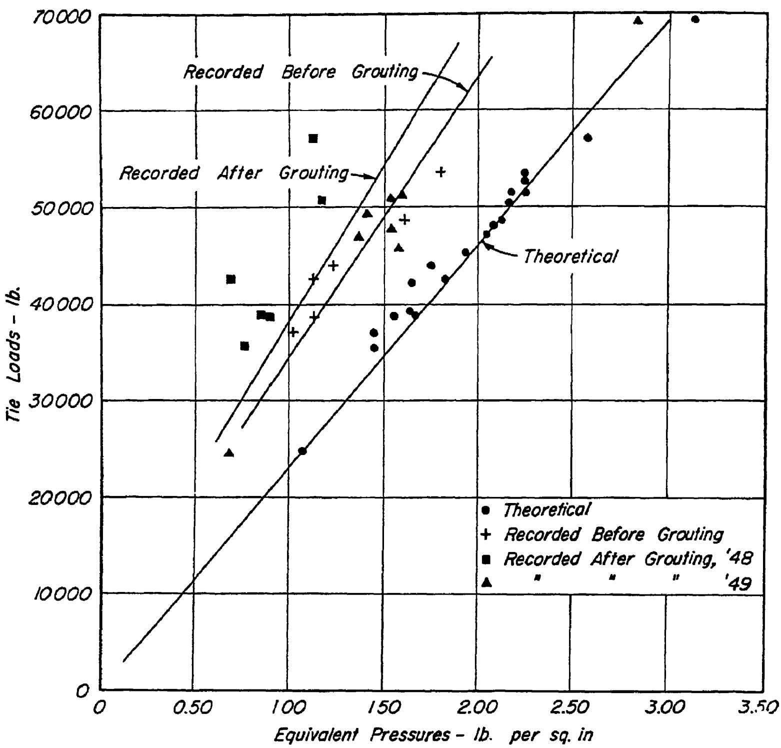


Fig. 2.—Relation of Soil Pressures to Tie Load.

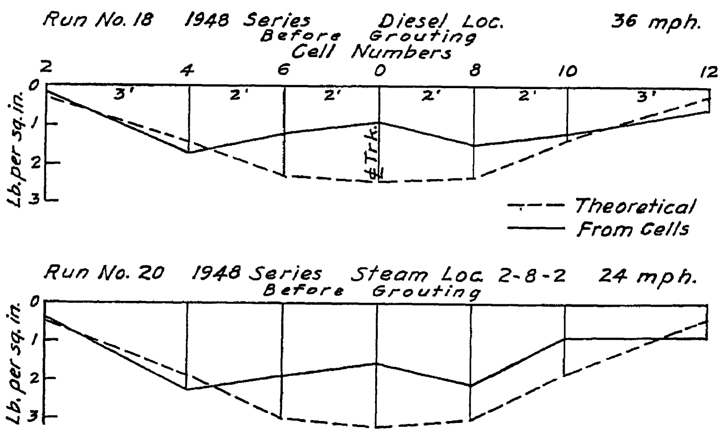


Fig. 3.—Vertical Pressure Distribution Top of Clay Subgrade, 56-in. Below Top of Tie on Section Through Tie No. 3.

son's ratio of 0.5. For these pressures there is fairly close agreement between the theoretical and the recorded pressures, for the runs prior to grouting. Immediately after grouting, however, cell No. 9 showed reversal of the direction of the indicated pressure which, if correct, puts the soil at this position into tension. The recorded pressures after grouting, except for the area indicated as tension, in general, run greater than the theoretical pressures, but if the tensional area is considered the average or weighted pressures are in fair agreement.

The full significance of the indicated tension has not been established. When the cells were removed from the roadbed No. 9 was about 50 percent covered with grout, with a 1 to 2-in. seam running upward toward the rail. The cell itself calibrated correctly after the trench was open, before and after removal from the ground. All circuits were checked and there appears to be no possibility that the reversal was due to electrical causes. Cell No. 10 closely adjacent to No. 9, but measuring vertical pressure, was in no ways affected outside of normal. It is possible that the grout seam and the general effect of the stabilization in producing rigid spots broke up the normal stress transmission through elastic materials, resulting in a stress reversal. Additional study and analysis are necessary on this point.

Variations in Load per Tie

A study of the distribution of the total load among the five ties on which loads were recorded shows that the center tie, directly over the pressure cells, carried only 11.7 percent of the load, against a normal of 20 percent if the load was uniform on all ties. As this tie loading has the greatest influence on the pressure cells, the recorded pressures as well as the theoretical have values lower than would occur under tie No. 1 for a similar load system, which carried an average of 27.1 percent of the load for the runs listed. This unequal distribution apparently is characteristic of track as shown by the tie plate loads reported by Committee 5—Track, in the Proceedings, Vol. 50, 1949, pages 18–50. For the pressure cell installation the center tie was tamped continually in an attempt to produce average loads. As it was over the trench excavated for placement of the pressure cell full loads could not be maintained. The oscillograph records indicate that as the first wheel appeared over the cells the load would drop. As the pressures in the center of the track showed no tendency to increase with time and additional tamping an arching effect is indicated.

An oscillograph record for a typical run is reproduced as Fig. 6. While in general the greatest pressures are registered under the locomotive, there were times when loaded cars give readings of equal magnitude. From the figure the vibratory effect of cast iron car wheels can be noted. It is possible that this type of loading is more detrimental to the subgrade than a larger more steady load. The numerous stress reversals with the consequent strains can act as a pump or bellows where free water is present. This water driven into the soil will destroy compaction and reduce the strength of the subgrade. Laboratory experimental data along this line are given in Part 3 of the roadbed stabilization report for this year under the assignment of subcommittee 6 (a). This report also covers the effect of grouting on simulated subgrades.

The pressure cell installation included cell measurements in two planes only. For a complete analysis including principal stresses and shears a three-plane system is required. Consequently no computations for these factors are included in this report. although on the basis of the comparison of theoretical and recorded pressures these could be assumed from the data obtained.

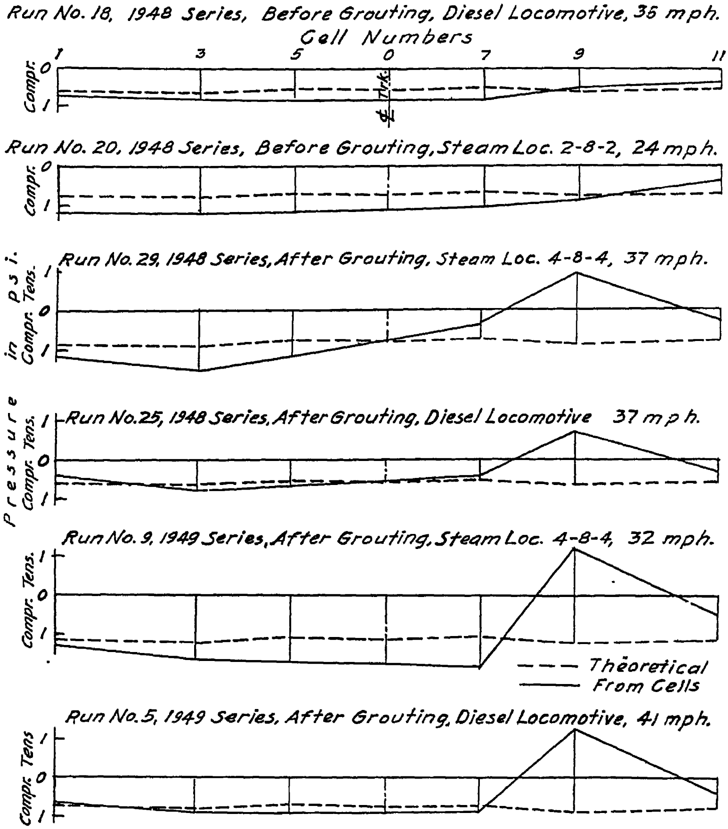


Fig. 5.—Horizontal Pressure Distribution Top of Clay Subgrade, 56 in. Below Top of Tie on Section Through Tie No. 3.

Also the low pressures under the center of the ties further support this conclusion. Full verification of the possibility that the pressure cells are recording properly would require a larger installation of pressure cells to cover the wider distribution of pressures indicated.

On Fig. 2 the load pressure points for the runs after grouting show a different value than those prior to grouting. While this is not so marked as the previous relationship between theoretical and recorded pressures, the tendency toward reduced pressure readings for equivalent loads is apparent. It is to be noted, however, from Table 1 that the ratios of recorded to theoretical pressures are lower for the 1948 after-grouting series than for the 1949 series. The theoretical pressures are, of course, not affected by grouting. This apparent reduction in recorded pressures after grouting probably results from the solidification of the ballast and the formation of rigid sections through which the load is transmitted, by-passing the pressure cells. It may also represent the time elimination of the first effects of the cement grout. Fig. 4 shows the theoretical and recorded vertical pressure distribution over the section containing the pressure cells for several typical runs of both the 1948 and 1949 series after grouting.

The horizontal pressure distribution over this same section is shown for six typical runs in Fig. 5. This distribution is also computed from Newmark's charts using a Pois-

Summary

The results obtained during this investigation indicate that it is possible to obtain very good records of subgrade pressures qualitatively, by means of pressure cells of AAR design and that there are very good indications that the records are faithful quantitatively. Further investigation with extended coverage is required to further substantiate this indication.

Grout stabilization is indicated as changing the load distribution. This effect is more pronounced immediately after treatment. Here too further investigation is required. Further installations should be in a wider trench to reduce possible arching effect. The stabilization also affects horizontal pressures on vertical planes parallel to the track for the section under test.

Steam locomotives create greater subgrade pressure intensities than diesels. This increase is greater than the ratio of locomotive axle loads.

The results of the present investigation justify additional work of greater proportions. It is understood that the results reported here are for conditions of track, loads, ballast, subgrade soils and moisture present on the section tested. Their application to other condiitons must be established by continued research.

Part II. First Progress Report of the Investigation of Stability of Compacted Embankments

By H. O. Ireland and Emilio Rosenblueth

Special Research Associate and Research Graduate Assistant University of Illinois

Introduction

Prior to about 1930, railroad fills were constructed almost exclusively by end dumping or by filling from trestles. The settlement of the completed embankments was appreciable and varied with the character of fill materials used. It was customary to operate trains at slow speeds over these fills for several years until settlement became negligible, whereupon high grade ballast was laid and the speed of trains increased.

In the early 1930's, methods developed for the construction of earth dams were first employed in building railroad embankments. These included compaction in layers by means of rollers, control of the water content of the soil, and, to some extent, selection of borrow material to eliminate particularly unstable soils.

Most fills constructed by modern methods have been satisfactory, even when high speed trains have operated over them immediately on completion. However, in several instances these procedures have not led to good results, and high maintenance expenditures have been required. Several examples have been listed in the progress reports on investigation of methods of roadbed stabilization. They include the relocation of the Chicago, Rock Island & Pacific Railroad between Mercer and Princeton, Mo., (Proceedings AREA, Vol. 47, 1946, page 326); the Missouri–Kansas–Texas Lines on the Pottsboro–Sadler revision (Proceedings AREA, Vol. 50, 1949, page 664); and the Illinois Central Railroad at Coldwater, Miss. (Proceedings AREA, Vol. 50, 1949, page 663).

Inasmuch as the cost of compaction and moisture content control is relatively great, it is important to learn the reasons for unsatisfactory behavior of fills constructed by these methods. Therefore, an investigation to determine the significant factors has been initiated. Thus far, the principal field evidence has been obtained from the Pottsboro-Sadler revision of the M–K–T.

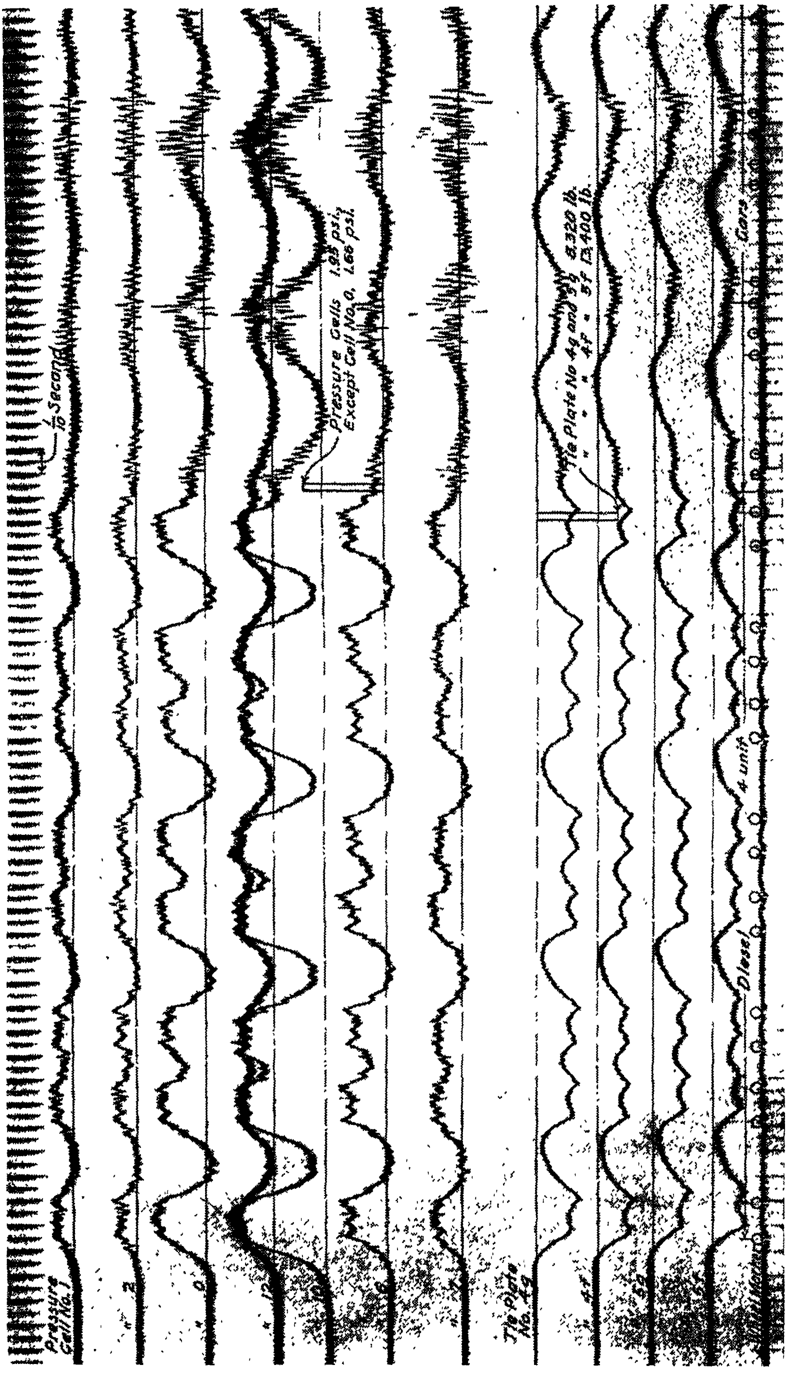


Fig. 6.—Oscillograph Record for Run No. 5, 1949.

Description of Revision

Construction of Denison dam necessitated the relocation of the M-K-T for approximately eight miles in northern Texas. Whereas the original line traversed the territory on low fills and through shallow cuts, the new line includes fills as high as 35 ft. and cuts as deep as 33 ft. The revision was put into service in 1944. Instability of both cuts and fills became evident almost immediately. The average annual excess maintenance costs since 1944 have been estimated at about $2 per track foot.

The unstable fills consist of a clay shale compacted in layers with a final thickness of 8 in., placed at the optimum moisture content, and rolled to a specified degree of compaction with sheepsfoot rollers exerting a foot pressure of at least 350 psi. The specification required that materials having a maximum dry density less than 115 lb. per cu. ft. should be compacted to 95 percent of the modified AASHO maximum density. Materials having a maximum dry density equal to or greater than 115 lb. per cu. ft. were compacted to 90 percent of the AASHO maximum.

The standard slope for fills was established at 1½ to 1 wherever the base of the fill rested on ground not subject to innundation by the reservoir. Where the base would be subject to such innundation the standard slope was established at 2 to 1.

Within the five-year period of operation, at least two types of instability have devloped. These consist of ballast pockets now as deep as 9 ft. and slides which usually begin as tension cracks near the crests of the slopes. The slides break out of the fill above the base. There is no indication that the fills receive inadequate support from the underlying foundation materials.

To alleviate or correct the difficulties, many slopes have been flattened or widened with berms. In several localities extensive installations of vertically driven ties and poles as well as French drains have been made. Slow orders are required much of the time along the revision.

The instability has developed in spite of the fact that the slopes have not yet been submerged by water in the reservoir of Denison dam.

Field Investigation

As a first step in investigating the causes of the difficulties, a survey of soil conditions was made at a 26-ft. fill at M. P. 677.8. A cross section of this fill is shown in Fig. 7. Because of unstable conditions, the additional material and berms were built up as shown in the figure.

The original data concerning the properties of the soil used as fill material were not available. Therefore, samples were taken from the borrow pit and tested according to the generally accepted procedures for such projects. In addition, two borings were made in the fill itself. Undisturbed as well as disturbed samples were used to investigate the properties of fill at the time of the field studies in August 1949. The results of the tests on the fill and borrow materials permit tentative conclusions concerning the causes of the instability.

Characteristics of Fill Material

The material from the borrow pit had the general properties indicated in Table 2. The Atterberg limits of the materials in the fill did not differ essentially from those in the borrow pit.

The maximum density and the optimum moisture content of the shaley clay as determined by laboratory tests depend somewhat on the size of the largest fragments used for the test. However, in any event, if the specifications were followed the moisture content at the time of placement of the fill should have been between 15 and 18 percent.

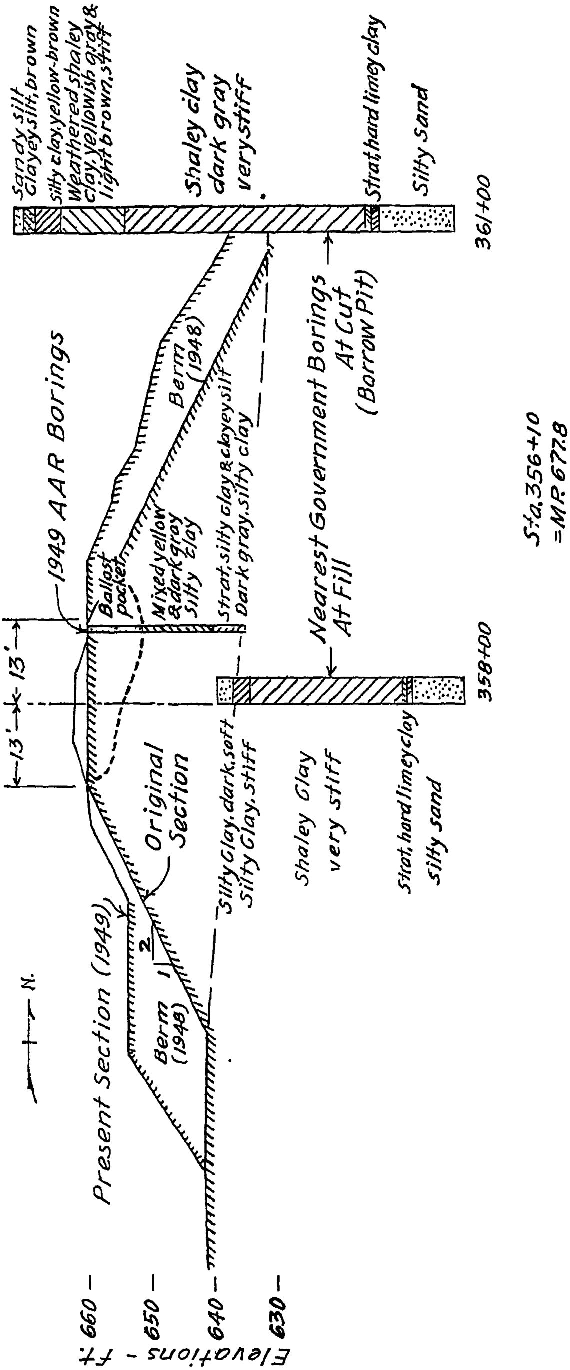


Fig. 7.—Cross Section Showing Record of Borings and Outlines of Original and Modified Embankment.

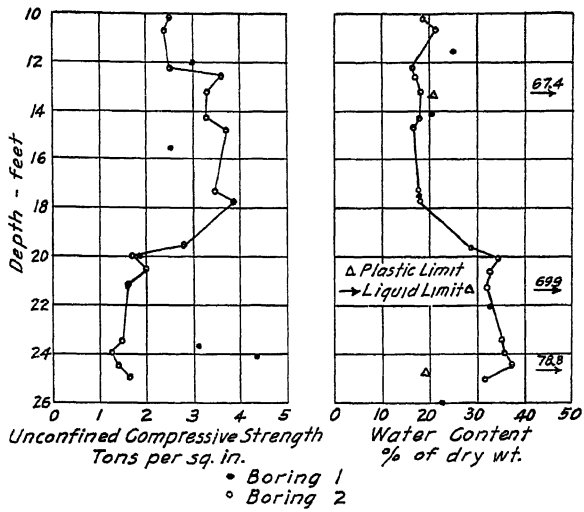
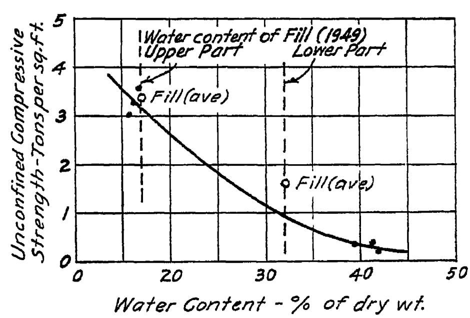


Fig. 8.—Relation of Depth of Fill to Compressive Strength and Water Content.

Fig. 9.—Relation of Water Content to Compressive Strength.



Several series of tests were made in the laboratory to determine whether the observed strengths of the fill material in 1949 were in agreement with the results of tests on the borrow pit material. In these tests, the shale was compacted to approximately 100 percent of the modified AASHO maximum value at the optimum moisture content. Unconfined compression tests were performed immediately on some specimens, whereas others were soaked until their moisture content exceeded that of the lower part of the fill material, and were then subjected to compression tests. The relation between strength and water content is shown in Fig. 9. On the same diagram are shown average values for the fill material. It may be concluded that the strength of the clay in the fill in 1949 was not less than that predicted on the basis of laboratory tests on the borrow pit material; indeed, it was somewhat greater. Hence, it does not seem that the unstable conditions can be attributed to any deterioration in the inherent quality of the clay shale with the passage of time, such as might be due to mineralogical or physical changes involved in the reversion of the shale into clay.

TABLE 2.—CHARACTERISTICS OF BORROW PIT MATERIAL

Liquid limit	65 to 86 percent
Plastic limit	25 to 28 percent
Plasticity index	40 to 60 percent
*Maximum dry density (max. size ¾ in.)	103.8 lb. per cu. ft.
*Optimum moisture content (max. size ¾ in.)	16.0 percent
*Maximum dry density (max. size ¼ in.)	113.9 lb. per cu. ft.
*Optimum moisture content (max. size ¼ in.)	17.4 percent

* Modified AASHO compaction test.

The borrow pit material displays no unusual characteristics except its relatively high plasticity. Several state highway departments prohibit the use of fill material having a liquid limit greater than 65 percent, because such materials are likely to have low shearing strength when wet and to experience large volume changes. However, many perfectly stable fills and some earth dams have been constructed of highly plastic material and the values of the Atterberg limits cannot be considered the final criteria for suitability.

Of greater importance is the character of the clay minerals that give rise to the plasticity of the material. Of the various clay minerals, the most active are the montmorillonites. The most familiar form of montmorillonite is bentonite. However, the mineral occurs in other forms all of which are capable of extremely large volume changes due to alteration of the water content. One sample of the borrow pit material and one of the fill material were subjected to mineralogical analyses by Dr. R. E. Grim. His results indicated that over 60 percent of both samples consisted of nontronite, a member of the montmorillonite group with a high iron content. This fact leads to the conclusion that unusual volume changes might be expected in the fill.

To check this conclusion, several samples from the fill were confined laterally, placed under small vertical pressures, and allowed to take up as much water as they would. Under a very small vertical pressure (12 lb. per sq. ft.), the volume of the material increased 23.4 percent. Under pressures on the order of 350 lb. per sq. ft., the swelling was approximately 4 percent. A pressure of about 1700 lb. per sq. ft., equivalent to about 10 ft. of fill, was necessary to prevent all swelling.

The volume changes determined by the swelling tests began at the moisture content of the sample as it existed in the fill in 1949. It is probable that the changes would have been greater had the initial moisture content in the tests been equal to that at the time the fill was placed.

Investigation of Fill

A general description of the material found in the 1949 AAR borings is indicated in Fig. 7. For comparison the logs of two borings made prior to construction are also shown. The boring at station 358 is typical of the material upon which the fill rests. That at station 361 is representative of the borrow pit materials.

Representative samples were taken from boring 1 and tested in the field.* Continuous samples were obtained in boring 2, and their moisture content and unconfined compressive strength determined in the laboratory. The results are shown in Fig. 8. It may be observed that the water content of the fill to a depth of about 19 ft. is essentially at the optimum value for compaction, whereas at greater depth the moisture content is approximately 32 percent, considerably above the optimum. The average compressive strengths above and below the discontinuity in water content are approximately 3.6 and 1.5 tons per sq. ft., respectively.

* The simple field procedure for sampling and testing the material is described in the appendix. It is applicable to many jobs involving cohesive soils.

Cause of Failures

It appears that the moisture content of the lower few feet of the fill has increased appreciably since construction, probably because of the rise of the groundwater table. This increase in water content has produced a definite and predictable decrease in strength. However, even the reduced strength is ample to prevent an ordinary shear failure within the body or at the base of the fill. Moreover, the field evidence appears conclusive that the seat of failure in most of the fills is well above the base. The surficial character of most of the slides is apparent, except where the slopes have bulged near the top on account of the development of extensive and deep ballast pockets. Since the cause of the formation of the ballast pockets is not within the scope of this report, only the causes of the slope failures will be considered.

It seems most probable that the slope failures are due primarily to volume changes in the uppermost few feet of the fill, where the confining pressures are small enough to permit significant swelling. The depth of the affected zone is undoubtedly increased by the development, during the summer, of large and deep shrinkage cracks, through which the entrance of the water necessary for swelling is facilitated. As the clay swells during the wet season, its strength becomes very small; some of the slides give the impression that the movement occurs as a slow, viscous flow.

Conclusion

The instability of the fills on the Pottsboro–Sadler revision on the M–K–T appears to be primarily the result of volume changes of the materials within a few feet of the surface, where the confining pressure is low. The volume changes, in turn, can be attributed to the high percentage of the clay mineral nontronite, a member of the montmorillonite group. The unsatisfactory behavior of this material would not have been indicated by any of the standard soil tests made in connection with fill materials, but would have been suggested by routine mineralogical analyses and confirmed by swelling tests.

Future Program

Studies and observations are being made at the Coldwater fills of the Illinois Central, and an extensive program of field observations and soil tests has been initiated in cooperation with the same railroad near Grenada, Miss. At the latter site, a relocation is under construction in connection with the Grenada dam and reservoir. It is planned to carry out field studies of the behavior of the fills for several years.

Appendix

Determination of Compressive Strength in the Field

The simple equipment developed for determining the unconfined compressive strength of clay fills appears suitable for field tests not only in connection with embankments but also foundations. The essential information concerning the strength of clay subsoils can be obtained without laboratory tests.

The borings at the Pottsboro–Sadler investigation were made by means of a power auger, Fig. 10. The auger was used primarily to clean out the hole to a given depth whereupon a sample was taken in a thin-walled steel tube 2 inches in diameter. The dimensions of the tube and details of the simple connection between the tube and its handle are shown in Fig. 11.

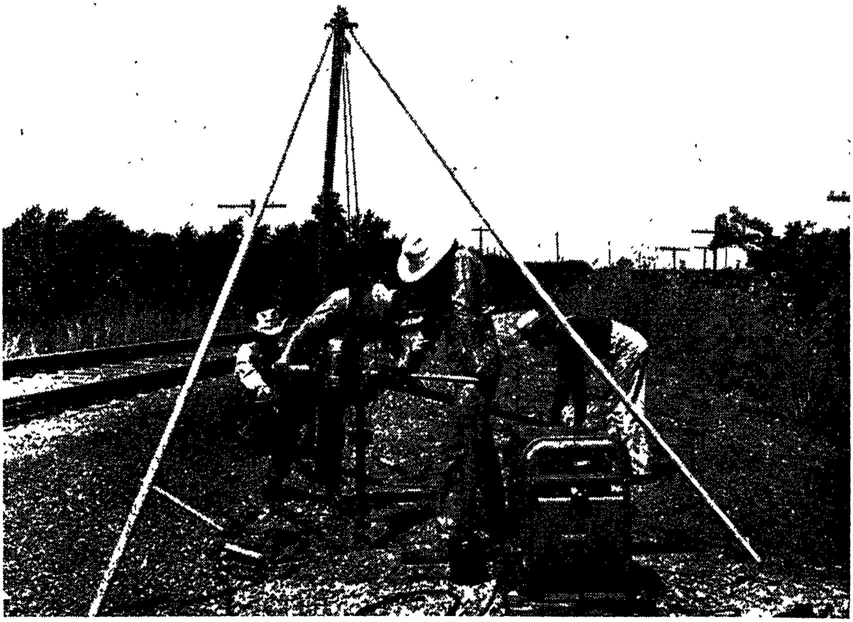


Fig. 10.—Gasoline-Electric Auger in Use.

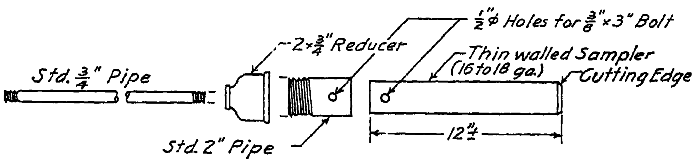


Fig. 11.—Drawing of Sampler Tube.

Fig. 12.—Portable Apparatus for Determining Strength of Soils.

The tube was lowered to the bottom of the hole and, if possible, pushed into the soil without driving. The handle was then rotated several times to break the sample loose at the bottom and the sampler withdrawn from the hole. After the cylindrical specimen of clay was pushed out of the thin-walled tube, a smaller specimen, generally 1 in. square and 1¾ in. high, was cut from the central part of the tube sample. This specimen was mounted in the portable testing machine.

A general view of the testing machine in operation is shown in Fig. 12. The apparatus consists of a beam through which load is applied to the sample. The load is measured by a simple spring balance. The shortening of the sample may be measured by observing the movement of the balance as a whole toward the hand of the operator. The load on the specimen is equal to twice that measured by the balance, and the shortening of the sample is half the movement of the balance.

Detailed drawings of the apparatus are shown in Fig. 13. The device can be disassembled and packed into a carrying case approximately 4 in. by 8 in. by 20 in. The equipment can be built for approximately $60.

After completion of a compression test, the specimen may be placed in a sealed jar until its moisture content can be determined. This value together with the compressive strength represents the information most commonly required for determining the supporting capacity of clay materials.

Report on Assignment 6

Roadway: Formation and Protection

B. H. Crosland (chairman. subcommittee), J. C. DeJarnette, Jr., R. A. Gravelle, F. W. Hillman, G. W. Payne, C. S. Robinson, F. H. Simpson, C. E. Webb, W. L. Young.

Your committee has been given three subassignments under the general assignment of Roadway formation and protection, namely: 6 (a) Roadbed stabilization; 6 (b) Construction and protection of roadbed across reservoir areas; specifications; and 6 (c) Chemical eradication of vegetation.

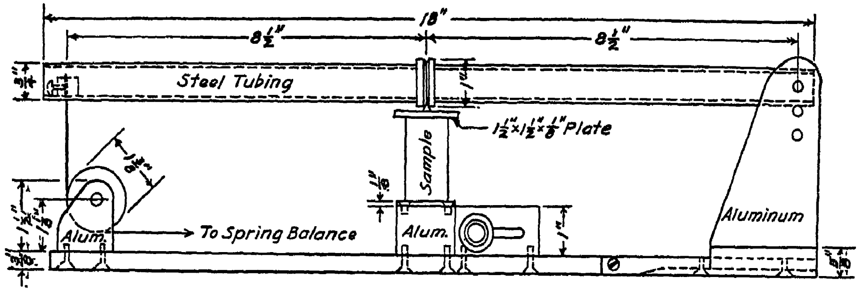
Each of the above assignments is studied by a special section of the subcommittee with its own section chairman, and reports on two of them are presented below. Comments and suggestions are particularly invited. It is requested that such comments be addressed to the section chairman.

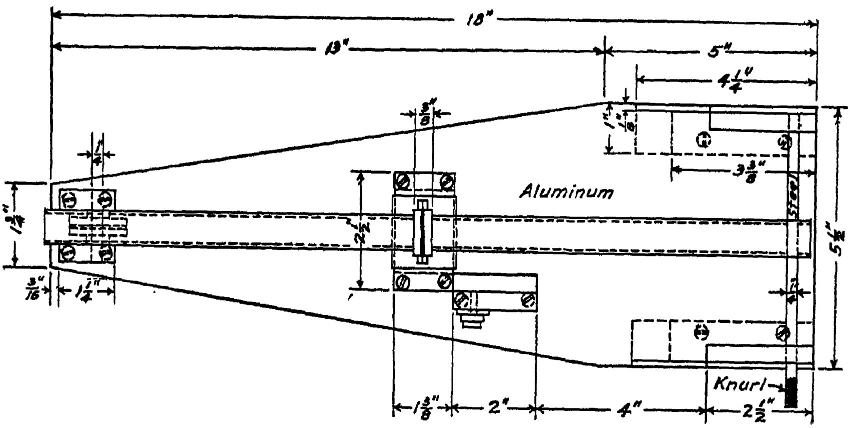
Report on Assignment 6 (a)

Roadbed Stabilization

F. H. Simpson (chairman section (a)), F. W. Hillman, W. L. Young.

The following report presented as information was prepared by the Engineering Division research staff and is divided into three parts. Part I covers field studies, results and maintenance data for roadbed stabilization. Part II gives the recommended procedures for various types of stabilization and Part III is the report on the laboratory study of stabilization conducted by the University of Illinois.





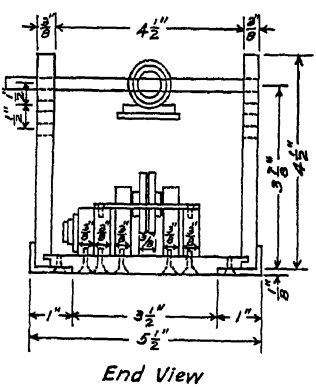


Fig. 13.—Side, Top and End Views Showing Details of Apparatus for Determining Strength of Soils.

A few general remarks on Parts I and II follow:

For pressure grouting the results are fully documented by records of savings, that are directly attributable to the treatment, for the years since stabilization. The amount and duration of these savings are usually sufficient to amortize the original cost within four years. These results are sufficiently favorable to place stabilization by grouting beyond the experimental state and in the category of recommended practice.

The first roadbed grouting on railroads was over a short section of the Pennsylvania Railroad near North Point, Md., where a water pocket was stabilized in 1936. This section is now 13 years old and the railroad has reported continued benefits. Limited stabilization by grouting was done on the Pennsylvania and other roads in succeeding years, and in 1941 the New York Central Railroad and the Atchison, Topeka & Santa Fe Railway started extended programs that have continued to the present time. More than 55 roads have used pressure grouting for roadbed stabilization. Each year additional roads use the method for certain of their subgrade problems.

Other methods of stabilization have also been very effective, but to evaluate the results definitely a service record and a knowledge of costs and maintenance savings must be built up. Tie and pole driving has been in use for many years and has generally given good results. However, not all installations have been successful, due to insufficient planning, and further investigation and maintenance cost data are necessary before definite conclusions as to the efficacy of this treatment under various conditions can be established. The records now available to the committee cover a range of conditions that is rather narrow both in geographical and pedological extent, but they do indicate that favorable results are usually obtained by the method over low fills on wet ground.

The sand pile and sand-filled blast hole methods are relatively new in their application to railroad subgrades, and more time and data are necessary for complete evaluation of their efficacy.

It is the hope of the committee that the merits of the various methods of stabilization will ultimately be evaluated so that the most effective and most economical means at a given site can be determined from a survey of fixed conditions.

The report on laboratory tests in Part III is highly interesting. Ballast pockets have been developed under laboratory conditions that bear very close resemblance to those occurring in roadbeds. Further, this report begins to explain the manner in which stabilization by pressure grouting produces results. A continuation of this work may lead to a more complete understanding of the factors involved in stabilization and thus permit many refinements in methods.

Part I. 1950 Report of the Investigation of Roadbed Stabilization

This is the fifth progress report on the investigation of methods and results of stabilization of railroad roadbeds, and has been conducted under sponsorship of Committee 1—Roadway and Ballast, by the Engineering Division research staff in cooperation with the Engineering Experiment Station of the University of Illinois. G. M. Magee, resarch engineer of the Engineering Division, AAR, and Dr. R. B. Peck, research professor of soil mechanics of the university staff, directed the work. Rockwell Smith, roadway engineer, research staff, performed the field work and prepared this portion of the report. Laboratory tests and research and the report on these activities were under the direction of Dr. Peck, assisted by Dr. T. H. Thornburn and H. O. Ireland, also of the university staff.

Field Studies and Results of Roadbed Stabilization

General

The investigation in 1949 included a study of the different methods and the costs of roadbed stabilization now in use, namely pressure grouting, tie and pole driving, sand piles and sand-filled blast holes. Grouting and maintenance costs prior to and following such stabilization have been tabulated and appear in Tables 1 and 2. These will be discussed in a following section.

Similar cost data for the other methods have not been obtained but arrangements have been made to secure some information of this type in 1950.

In the field work this year, considerable attention has been given to analyzing the underlying causes of instability in order to prescribe the most effective and most economical treatment. However until maintenance data for methods other than grouting have accumulated only general terms can be used in evaluating the conditions best suited for a particular type of stabilization. Part II of this report describes typical procedure for all the methods in current use and indicates those physical features of unstable track most likely to react favorably to a particular procedure.

Cost Data

The cost data in Table 1 for the Santa Fe and the New York Central show the results obtained for periods up to six years after grouting. There is no apparent trend toward increased maintenance cost with increased years of service. The results are very favorable, the savings in yearly maintenance are as a rule over 70 percent, and the cost of the work is generally amortized within a four year period.

Table 2 shows the record of grouting projects up to 4½ years old on 12 railroads. The lowest saving in percentage of the pregrouting maintenance cost is 46. Many of these projects return the cost of stabilization within 3 years. This is especially true of water pocket and soft track stabilization.

Sliding fills as a rule show a much greater acceptance of grout and a corresponding increase of original cost. Several, however, such as the Great Northern fill near Noyes, Minn., and the Wheeling & Lake Erie fill near Baltic, Ohio, both with very high acceptance, show sufficient maintenance savings to amortize the cost within five years.

It is difficult to conceive of any other maintenance expenditure that will yield returns equal to those of the dollar spent in judicious stabilization.

Permanence of the stabilization still deserves consideration, but records of 4, 6 and, in one case on the Pennsylvania, 13 years indicate that such stabilization is of long duration. The only known project that has ceased to remain stable is on the Pennsylvania, near Fort Wayne, Ind. This project was reported last year as showing continued savings for 10 years. This year it was reported as failing and the section was regrouted. The original cost was $1000 and the annual saving was 360 man-hours.

Fill Stabilization

In this report only two specific projects with several unusual features will be discussed. They are the grouting of a fill at Westgate, Va., on the Virginian Railway and the sand filled blast holes on the Southern Railway near Centralia, Ill.

The Virginian

In 1949 the Virginian stabilized a fill on its lines near Westgate, Va., approximately 20 miles east of Roanoke, that differed from previous fill stabilization in the character of the soils involved. Most of this type of work that has come to the attention of this investigation has been in clay soils of medium to high plasticity. The soils in the Westgate

there is an appreciable saving in operational costs by the removal of speed restrictions from a track carrying 16 million gross tons annually. Fig. 2 shows the completed fill.

The Southern

Between M. P. 69 and M. P. 77 near Centralia, Ill., on the Louisville–St. Louis division, the Southern Railway has stabilized approximately 5000 track feet this year by means of sand filled blast holes. This work was done on short sections of track where pushes and squeezes were common, usually in cuts but on some fills less than four feet in height. A general description of the method is given in Part II of this report. Fig. 3 shows a view of typical conditions.

The line through this territory is a single track over rolling country with alternate cuts and fills. The soils are clay tills of medium to high plasticity susceptible to the development of pockets in the subgrade. The ballast is fine chatt. Ballast pockets have a depth of three to four feet and contain free water.

For one section observed the filling required an average of 11 cu. ft. of dry loose sand per hole. Where both sides of the track are treated, this is equivalent to 16.5 cu. ft. of sand per track foot. This amount of sand introduced into a clay subgrade should be of considerable benefit and the service record to date so indicates.

There is no evidence at present that this sand becomes an intimate mixture with the clay. Samples of the clay taken before sand filling and within 9 in. of a sand filled hole had almost identical gradation. The field moisture was, however, somewhat lower after the filling. This may be a result of the blasting and is, of course, of value in producing increased stability. No knowledge of the disposal of the excess moisture has been obtained, but it is possibly dispersed into the subgrade and ballast by concussion.

The stabilization in this territory has cost approximately $3 per track foot where both sides of the track were treated. No record is as yet available as to the amount of maintenance savings, but supervisory officials are unanimous in declaring that the stabilization has corrected soft track and squeezes for the sections treated.

In 1947 to 1949, incl., the Southern also treated with the sand blast method considerable trackage between Alexandria and Culpepper, Va., in double-track territory. This work has usually been performed on low fills, although one fill 15 ft. high and part of one cut 18 ft. deep were included.

The procedure in this area was very similar to that described in Part II of this report, but it varied in several respects. A two-inch pipe spud was driven with air hammers replacing the earth auger. On the higher fills, after the first blast a second charge of dynamite was placed and the hole filled with sand. This charge was then set off and the hole again filled. Also, on fill work, an additional hole was blasted near the shoulder every 15 to 20 ft. where it would form an opening for drainage to the side. This, of course, was not possible in cuts and reliance was placed on vertical drainage.

The soils in this area consist of a sandy topsoil underlain by a shaly red clay which tends to retard downward percolation of water. The fills are composed principally of clay of medium to high plasticity. Apparently the shaly clay stratum is lubricated and weakened by ground water and the fills are moving in this zone. In treatment the blasts are made below or, in this layer, to roughen it and key the fill to the ground. The results have been very satisfactory, although as yet no definite figures are available as to the amount of maintenance savings. The cost of the work is about $3 to $3.50 per embankment foot where both sides of the tracks are treated.

fill, on the basis of grain size, would be classified as silty sands, but their action under load is unusual.

Along the slopes of the Appalachian mountains and auxiliary ranges, the soils have largely been developed from decomposed schists and granites. Subsequent weathering has produced a reddish soil consisting of a sandy topsoil and a second horizon clay of low plasticity. The subsoil, however, is a light, fluffy, highly micaceous material. It is slightly plastic to nonplastic, but is very elastic so that it rebounds upon removal of loads. Compaction of the material is difficult, and the compacted material has a tendency to swell.

The Westgate fill, a section of high maintenance costs for years, was constructed of material of this type. The fill ¼ mile to the west, of comparable height and slope, was construction from the upper horizons of slightly plastic clay and has shown no indication of instability such as has been recorded for the Westgate fill.

The fill, about 40 years old, is approximately 65 ft. in height and runs across a narrow valley for about 400 ft. The valley floor has a slope to the north, of three to four percent, and especially in wet weather the track would go out of cross level, and maintenance was required two or three times weekly. The instability was further evidenced by bulging slopes. A speed restriction of 12 mph. was in effect.

The grouting procedure was typical for fills of these characteristics. Injections along each slope with holes on a gridwork about 10 ft. apart were followed by injections from the top of the grade. Pneumatic pressure with a mix of 1 part cement to 4 parts sand was used. Acceptance, costs and estimated savings are listed in Table 2. Fig. 1 shows a view during grouting.

Experience in the six months since grouting has indicated excellent results. Eight inches of rain in one week in mid-July produced no reaction in the fill, whereas records for previous years, showed that continual maintenance was required during and after such wet periods. In addition to the direct and assessable savings in maintenance costs

Fig. 1.—Grouting Operation on the Westgate Fill.

Part II. Suggested Procedure For Roadbed Stabilization

General

The following discussion may serve as a general guide to the primary considerations and practices involved in roadbed stabilization. It is not intended to replace the practices evolved by various roads in the light of their experience. It is rather a résumé of the various procedures which have been successful. These procedures include pressure grouting, tie and pole driving, sand-filled spud holes and sand-filled blast holes.

Preliminary Investigation

Before stabilization is undertaken, it is essential to make an investigation of the conditions involved. Instability can be caused by a number of different factors, singly or in combination, and may be evidenced in a variety of ways. The purpose of the investigation or survey is to determine the type and depth of the instability, the soil and moisture conditions, and from these the most effective and economical method of correction. A tabulation of the more common types of instability and a brief discussion of each follow:

1. *Water or Ballast Pockets.*—These are indicated by squeezes or push-ups beyond the ends of the tie. They result in soft track, requiring excessive expenditures to maintain line and surface. Ballast pockets occur in the more plastic soils. They may attain a depth of over 10 ft. and on fills may develop into slope failures. Their presence and character are well known to all maintenance men. The investigation should include the determination of the extent and depth of the pockets, the type of soil in the subgrade, and the amount of water present.

2. *Slides.*—For this purpose slides may be classified into three general categories:

(a) *Slope failures resulting from a failure of the soil in shear.* In perfectly homogenous clays the sliding occurs along a nearly circular path (Fig. 4.). Since few railroad embankments are even approximately uniform in strength or composition, most slope failures have only a rough similarity to the ideal type shown in the figure.

(b) *Sliding failure along a lubricated surface.* Fig. 5 shows a diagrammatic sketch of an actual condition illustrating this type of failure. This condition is most often encountered on side hill fills or cut and fill sections. The plane of sliding is often lubricated by seepage or water from the fill. This type of failure is often combined with slope failures.

(c) *Foundation failures.* Where the weight of the fill overstresses the foundation this type of failure occurs. It is manifested in several ways. The least serious is a more or less vertical subsidence due to the consolidation of the underlying foundation by the weight of the fill. The movement is slow and is not a problem in embankments of railroads in service for a number of years. A more serious condition is encountered where the underlying material is displaced laterally. This can occur steadily or intermittently over many years. It is manifested by heaving of the ground surface beyond the toes of the fill. Fig. 6 is an idealized sketch of a foundation failure. Such failures are most common in swamps but soft clay can cause a similar condition, and for this material the instability is often of long duration. The slope, height, depth of weak subsoil, and of fill and subsoil are the principal determining factors in speed and duration of movements.

Fig. 2.—Appearance of the Fill After Completion of the Grouting.

Fig. 3.—Track of Southern Railway Near Centralia, Ill.

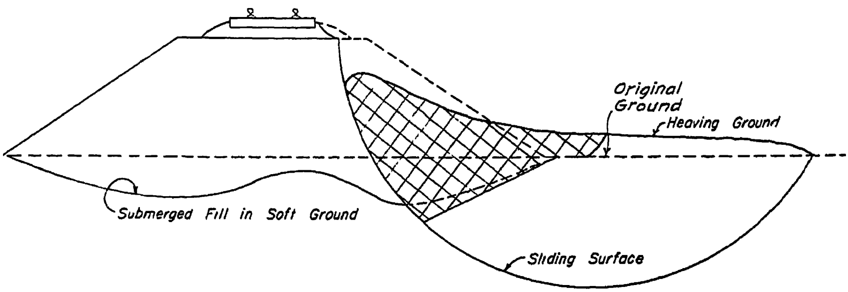


Fig. 6.—Pressure Grouting. Diagrammatic Sketch Showing Foundation Failure.

The investigation of slide sections is more difficult than that for ballast pockets. The survey should attempt to locate the surface of sliding because successful treatment demands that friction and strength be restored across this area. Also, the type of slide should be determined. In some cases full exploration may require considerable effort. Deep borings may be needed. Carefully made borings and simple soil tests will usually indicate the depth and source of trouble. For foundation failures the depth and strength of the underlying material should also be ascertained.

It is seldom in practice that any instability can be categorically classified. Because of the uncertain and variable characteristics of soil material, the action of earth structures does not conform to ideal analyses based on perfectly plastic material, having uniform characteristics.

The above discussion applies for any method of stabilization proposed. It may help to determine the most adequate process to be used. In the following, each process of stabilization is considered separately, with remarks as to the conditions that are best treated by the process under discussion.

Stabilization by Pressure Grouting

General

This process consists basically of the injection under pressure of cement-sand slurries into the subgrade or embankment. Two different methods of developing the pressure are common; namely, the use of compressed air and the use of a piston arrangement for producing hydraulic pressure.

Pressure grouting has proved generally successful in the correction of soft track caused by water pockets, especially on fills. Complete correction with a single treatment in cuts is more difficult because of reduced grout acceptance. However, progressive grouting with two or three applications either in a single or successive years will usually stabilize cuts to an extent that will more than amortize the cost. In general, grouting for stabilization of water pocketed soft track is the most economical method so far devised.

For stabilization of water or ballast pockets a grout acceptance of less than one cubic foot per track foot will probably give only temporary correction. Grout acceptance of two cubic feet or over will probably insure sufficient permanence to pay for itself. These statements, however, are not to be construed as indicating that it is only necessary to produce a grout acceptance of two cubic feet per track foot to procure stabilization. For ballast pockets care should be taken to achieve full acceptance before refusal or breakout.

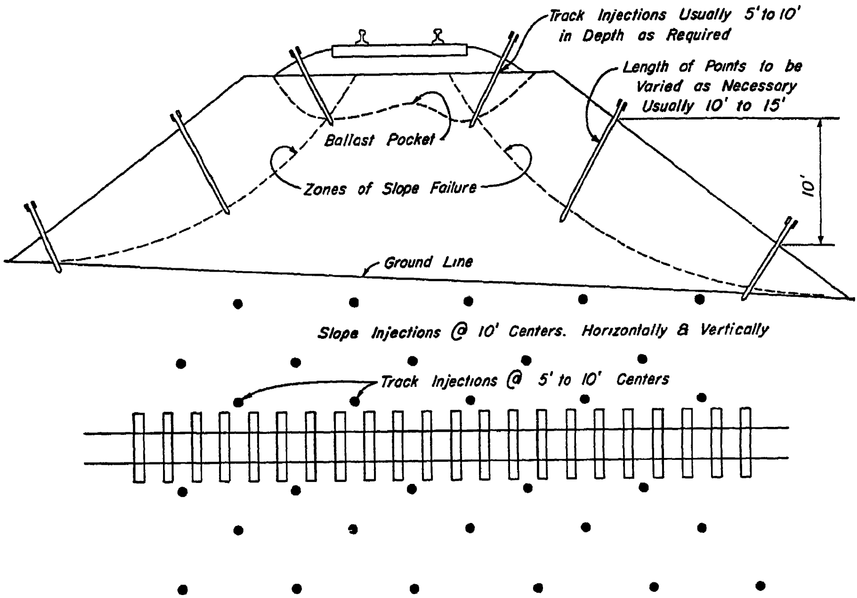


Fig. 4.—Pressure Grouting. Typical Injection Plan for Fill Slope Failures.

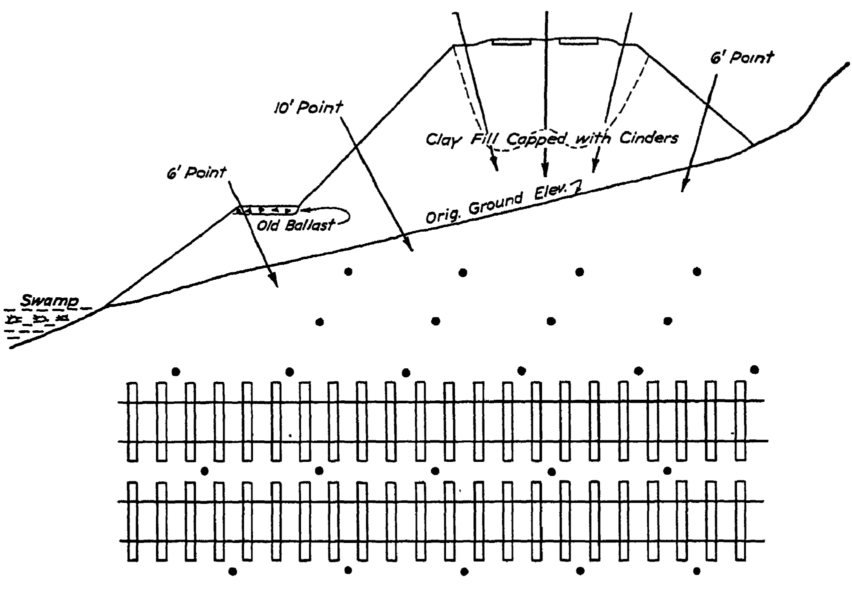


Fig. 5.—Pressure Grouting. Fill Sliding on Foundation and Typical Injection Plan.

The proportions of the mix are determined to a large extent by the policy of the road and the purpose and type of grouting. Labor costs are by far the greatest factors in this type of stabilization and savings in cement costs by the use of lean harsh mixtures may be nullified by line plugs or by failure to procure adequate penetration. Where it is desired to penetrate the coarse ballast in the bottom of a deep pocket the richer mixes are often used. Where the pockets are relatively shallow, less than five feet, mixtures of the order of one to four may be more desirable to avoid setting the ties and producing too much cementing strength in the upper ballast. Where acceptance is high, the cement content of the mixture may be reduced without apparent effect on the results obtained.

Certain conditions may arise where a cement-water mixture only is indicated, such as tunnel floors on rock or shale, or in roadbeds where acceptance is low and grout penetration difficult to obtain.

Asphalt emulsion is often used as a lubricant to produce better flow of the grout through the lines and appears to be of considerable value in reducing wear in hydraulic equipment. When asphalt emulsion is used, the amount applied ranges from 0.1 to 0.2 gal. per cu. ft. of dry ingredients.

Note: It has been suggested that the gradation of the solid particles in a grouting slurry should conform to the formula: $p = \frac{d}{D}$ where p is the percentage smaller than any grain size d, and D is the maximum size. In grouting slurries where the maximum size corresponds to the No. 20 sieve, (grain size 0.84mm.) this formula requires 71 percent to pass the No. 60 sieve (0.25mm.), 42 percent the No. 100 sieve (0.149mm.), and 30 percent the No. 200 sieve (0.074mm.). This refinement in gradation is not required, but slurries for which the gradation curve approaches that given by the formula are very satisfactory for injection and appear to segregate less readily. For a discussion on slurry mixtures see the Proccdings, Vol. 48, 1947, page 492.

4. *Procedure.*—The results of the preliminary investigation will determine the depth of the pockets and the severity of the moisture conditions in the pockets. Injections should be placed accordingly. Common practice is to space injections at 5 to 10 ft., staggered, along each side of the track. The closer spacing is used if there are indications of considerable variation in the depth of the ballast. Fig. 7 shows a typical layout of injection holes diagrammatically.

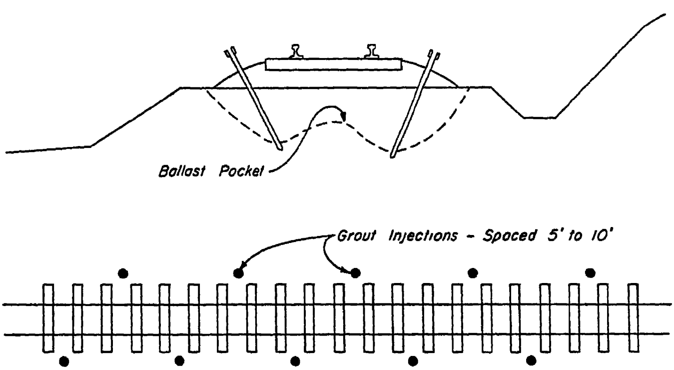


Fig. 7.—Pressure Grouting. Typical Injection Plan for Ballast Pockets.

Ballast Pockets

1. *Equipment.*—Basic equipment required for pneumatic grouting consists of a mixer and an injector pressure tank or combination thereof. The tank should be equipped with agitator paddles attached to a power-driven shaft, even if used only for injection purposes, to reduce separation of the grout materials. The tank can be shop fabricated or commercially produced. The usual capacity is approximately five cubic feet of dry material.

For hydraulic pressure grouting, a mud-jack or other machine must be provided to mix the slurry mechanically and supply it to the grout line under pressure through direct piston action.

Injection points of varied lengths, 5 ft. to 10 ft., are adequate for most ballast pocket stabilization. These can be purchased commercially or made in the shops. Heavy duty pipe equipped with couplings to provide variable length can be used. All points must be equipped with suitable heads to withstand driving. The points may be open ended or pointed with openings cut above the point.

Grout line hose is usually 1¼ in. inside diameter of heavy duty quality. Lines and points may be equipped with glad-hand couplings for speed in handling. A length of 200 ft. of hose is usually sufficient.

An air compressor of 105 cu. ft. capacity will be adequate to supply one injector tank and the air hammers. The air hammers should be provided with a special chuck to fit the driving head on the injection points or pipes. Where it is necessary to drive points through coarse ballast, a hammer weighing 50 lb. or more is advisable.

Other tools should include point pullers, wrenches as required and standard small tools. Unless the sand is absolutely free of all oversize particles or lumps, a sand screen is necessary to minimize plugging in the grout lines. This screen may be constructed of ¼-in. mesh screen cloth or slotted cloth. A screen is usually included in hydraulic equipment.

2. *Materials.*—Best results are obtained by the use of a rather fine rounded sand such as dune or beach sand. If possible 100 percent should pass the No. 20 mesh sieve and more than 80 percent the No. 40 sieve. As much as 20 percent passing the No. 200 sieve is permissible if the material is of such character as not to ball up in the mixer. Many local sources of suitable sand are available and the gradation, other than the maximum size, is relatively unimportant. This consideration permits the use of a sand that will be relatively inexpensive. Many roads have developed their own sources. Rather coarse sands can also be used but difficulties with line plugs, etc., tend to develop more readily. Finer gradations will permit the use of less cement if desired. See the Proceedings, Vol. 48, 1947.

Standard portland cement (Type I) is usually used, although good results have been obtained with air entraining cement of similar characteristics (Type IA). It has been reported that the air entraining cement reduces friction and line plugs to some extent. The air entraining qualities are not of value in the grout after injection.

3. *Mixtures.*—The usual mixtures for pneumatic grouting vary from one part cement with one part sand to one part cement with seven parts sand. For hydraulic grouting, mixtures up to one part cement with 32 parts sand have been used. The type and gradation of sand will determine to a large extent the amount of sand that can be used without operational difficulties. Water requirements vary from 3 to 6 gal. per cu. ft. of loose material depending on the amount of moisture in the sand. Fly-ash is often used to supply additional fines to the sand and reduce cement requirements. It is a by-product of steam power plants burning powdered coal and is collected on the electrical precipitators. Pulverized limestone will also serve this purpose.

grouting, the track usually requires a clean-up to eliminate grout in the top ballast, and a general spotting to smooth out any irregularities produced by the grout under pressure.

Fills

1. *Equipment.*—Same as for ballast pockets.

2. *Sand.*—Same as for ballast pockets.

3. *Mixtures.*—Considerations set forth for slurries for ballast pocket injections apply also for fill stabilization.

4. *Procedure.*—It is the usual practice on sliding fills to grout the slopes, starting at the bottom or part way up the slope, so that the first injections will occur in the vicinity of original ground or in the area that the preliminary investigation has shown is the surface of failure. The length of injection points is adjusted to reach the desired depth. In this scheme of stabilization, 15-ft. points are usually the longest required, and often 10 or 12 ft. will be sufficient. Injections spaced at 10-ft. intervals longitudinally and at 10 ft. vertically in a grid pattern will usually be sufficient but if needed, additional injections may be made. Figs. 4 and 5 show suggested layouts diagrammatically. Most sliding fills are weaker on one side and where this is apparent, injections on the more stable slope can be reduced below the normal pattern. Injections along the track are usually made last. It is often possible to reach the failure zone or zones from the top of the roadbed by the use of sectionalized injection pipes driven to the required depth, and in some cases this may be the best method. However, it appears that 20 ft. is about the practical and economical limit, beyond which the cost and uncertainty of driving and pulling will favor slope injections on most projects.

In driving injection points through the ballast bull points are sometimes used to a depth up to five feet. The point then is pulled and the injection point inserted and driven by the air hammer to the required depth. Water or grout is forced through the points during driving if pointed-end pipes are used. Bolt or rivet-plugged, open-end pipes must be rodded out prior to injection. In fill stabilization, driving the points while forcing grout or water through them has much to recommend it. Areas of acceptance can be detected in which it is of value to permit grout penetration even if not at the predetermined depth. As mentioned previously, injection of water prior to grout is a requirement where the point penetrates cinders or fine sand.

Grouting is continued through a point until it breaks or until it raises the track, except where acceptance is extremely high and there is reason to suspect that the grout is escaping unseen. In these areas an arbitrary limit such as 150 cu. ft. may be placed on the acceptance. After this limit has been reached, injection is stopped and grouting transferred to another point. After a suitable interval of one day or longer, grouting may again be tried at the location of high acceptance.

There are no data to show how much of the grout pumped into a fill is of value in the stabilization. There are some indications that complete and full acceptance is not required. These indications have been obtained from sections where the acceptance has been limited to a given amount short of break-out. They apply only to areas of very high requirements, such as fills of broken rock, etc. Where acceptance averages five percent or less of the theoretical volume of the fill, it is doubtful if limitation of grout acceptance should be specified except for individual injections. Thickening of the slurry may also be advisable in areas of high acceptance.

Piling

See Manual, pages 66.081–66.084.

Injection points may be driven either vertically between ties and close to the rail or on an inward slope from near the end of the tie so that the injection end is approximately under the rail. In either case care should be taken that the grout will flow out of the point and into the pocket. The point should penetrate through the pocket and a few inches into the subgrade material. A change in driving resistance will usually determine the correct depth if this has not been previously determined for all locations. Pneumatic hammers are used almost exclusively for driving points, although at times the points have been sledge driven. Bull points are sometimes used in ballast sections prior to the insertion of the injection points.

Where open-end points are used the open end should be plugged with a rivet or track bolt held in place with paper wrapping. Prior to grouting, this plug must be rodded out and the point pulled up a few inches. Where closed-end points are used it is necessary to circulate grout or water through the point during driving. Water is usually used as this opens channels for the grout. It is often advisable to inject water through the open-end points after driving, and in cinders and sand it is necessary. Usually 10 to 15 gal. are sufficient to insure grout acceptance.

The grout is mixed in the desired proportions, the line is attached to the injection point and pressure applied. Most compressors are governed at 85 to 100 psi. This pressure is required for efficient operation of the air hammers, but it is too high for most pneumatic grout injection. Some equipment has a reduction valve controlling this pressure at 60 psi. or below. In practice, however, the pressure can be controlled by hand operation of the air intake on the injector sufficiently to eliminate the bad features of too much pressure. In most cases the flow of the grout and the sweep of the agitator paddles in the tank keep the pressure at the injection point actually below that in the compressor storage tank. High pressures tend to segregate the slurry constituents and to hump the track before grout penetration is complete. In all cases, however, the air should be shut off before it penetrates into the hole. The completion of injection for a batch can be determined by holding the hose at its union with the injection point. The flow of the last of the slurry followed by air will cause a considerable jump in the hose apparent to the touch of the hand.

The pressure for hydraulic grouting is a function of the equipment. It is pulsating and may be much higher than in pneumatic grouting. Other details of procedure are identical for the pneumatic and hydraulic processes.

Injection is continued in any one hole until the grout breaks out or the track is raised objectionably, possibly ½ in. or less. The hose line is moved to an adjacent point and the process repeated. In pneumatic equipment an arrangement of two tanks, one above the other with gravity flow between, controlled by suitable valves, permits mixing to proceed simultaneously with injection. This arrangement eliminates most of the delay between batches and the addition of one or two men to the crew will raise daily production by approximately 50 percent. In hydraulic equipment, mixing and injections can usually proceed simultaneously.

Injection joints should be pulled soon after they have been used. All equipment should be washed thoroughly at the end of the day's work and at any interruption at any time. It is also advisable to provide fittings so that the grout hose can be attached directly to the air supply. This will facilitate cleaning if the line becomes plugged.

In grouting a section of soft track the injections should be continued at least one rail length beyond the confines of the unstable section. Confining the stabilization to the exact limits will often cause a soft section to develop at the end. Even with very little grout acceptance the length extended will serve as a run-off or transition zone. After

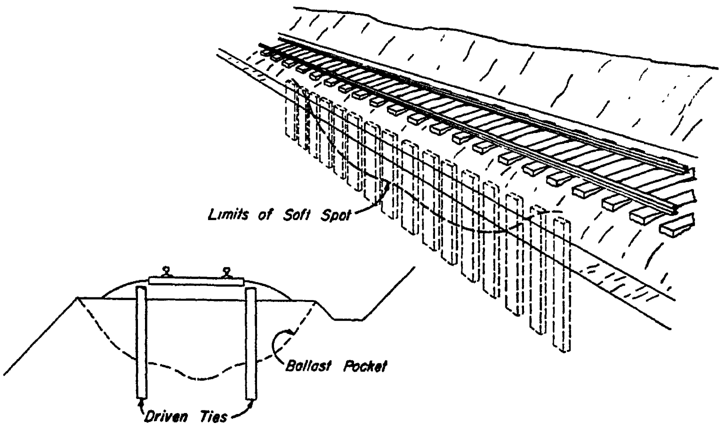


Fig. 8.—Tie and Pole Driving. Typical Treatment for Soft Track.

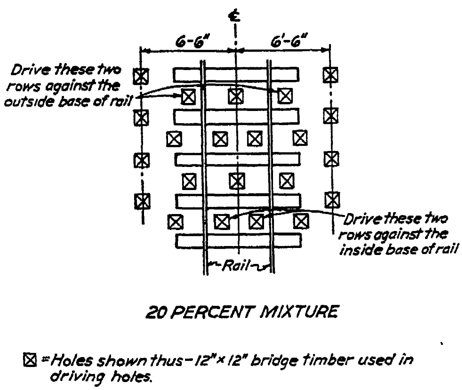


Fig. 9.—Sand Piles. Typical Treatment for Soft Track.

2. *Equipment.*—An on-track pile driver has been used commonly, but off-track or light weight on-track equipment could be developed for extensive work. Provision must be made for the stability against overturning required in pulling the spud. The spuds are usually butt ends of piles with diameters of 12 in. or greater, or 12-in. by 12-in. bridge timbers.

3. *Sand.*—The sand should be clean and sharp. Engine sand or concrete sand is usually suitable.

4. *Procedure.*—Preliminary investigations will disclose the depth of the pockets and these pockets must be penetrated by the spud hole. The severity of the instability will determine the degree of treatment. Fig. 9 shows the plan of the spud holes for what is called the 20-percent treatment. This treatment is usually sufficient for most soft track conditions caused by water pockets.

The spud is driven to the required depth and retracted. It is common practice to drive the spud to the depth from which it can be extracted by a direct pull on the line. This depth soon becomes apparent in the field. The holes are immediately filled with

Pole Driving

General

What is known as tie and pole driving consists of the driving ties or poles 8 to 20 ft. in length vertically along the track closely adjacent to the ends of the cross ties. Cull or unusable second-hand ties are often driven where 8 ft. lengths are indicated. See Fig. 8.

This method has been used extensively and with good results in the southwest on low fills over wet or swampy ground. In general, a height of fill of 6 ft. is the practical limit for this treatment, but some success has been attained in fills up to 10 ft. in height. Water pockets in cuts will also usually yield to correction by this method. Five-foot poles or ties have been used in cuts, but the results from the few installations observed have not been satisfactory. A general rule of thumb somewhat borne out by observations is to provide sufficient length of tie or pole so that at least 50 percent of the length will penetrate below the zone or zones of instability.

The factors tending to increase stability in this method probably include the additional strength of the soil structure accompanying the increase in density due to the driving, the containing influence of the poles, the direct support provided by the members acting as piles, and possibly vertical drainage. Preliminary investigation should disclose the conditions of instability, and the treatment should be designed as far as possible to take advantage of the above factors.

Savings effected by the pole treatment have not in general been a matter of record so there are no means of direct assessment of the value of the treatment. For one project, however, the costs of pole driving and of grouting on very similar sections were practically the same and the results were equivalent.

2. *Equipment.*—The principal item of equipment is a pole driver. Regular on-track pile drivers may be used, but for any extensive work with lengths up to 15 ft. a tractor equipped with suitable leads and a drop hammer will prove profitable. Small on-track drivers may also be used and a special on-track machine equipped with two leads has been used but is not commercially available.

3. *Materials.*—Cull ties may be used, as may be reclaimed ties if they retain sufficient strength to stand driving. Where available unpeeled poles of six inches minimum diameter are often economical.

4. *Procedure.*—The poles and ties are driven at about one foot beyond the end of each cross tie and to a depth approximately six inches below the top of the cross tie. See Fig. 8. Some raising of the track may result from the driving, and adequate run offs or a general surfacing must be made. Conditions of the section to be treated and preliminary investigations will determine if vertical ties or poles are needed on one or both sides of the track.

Sand-Filled Spud Holes

1. *General.*—This method of stabilization embraces the driving of a spud into the subgrade adjacent to and between the rails, removing the spud, and filling the hole with sand. See Fig. 9. The depth of treatment is limited to the depth from which the spud can be readily extracted, up to 10 ft. but usually less than 6 ft. This type of stabilization can be called sand piles. The success of the treatment apparently depends on the supporting power of the piles, plus the additional soil strength obtained through the consolidation of the subgrade and, in some cases, through vertical drainage. There may also be some modification of the soil characteristics by combination with the sand, but this has not as yet been established.

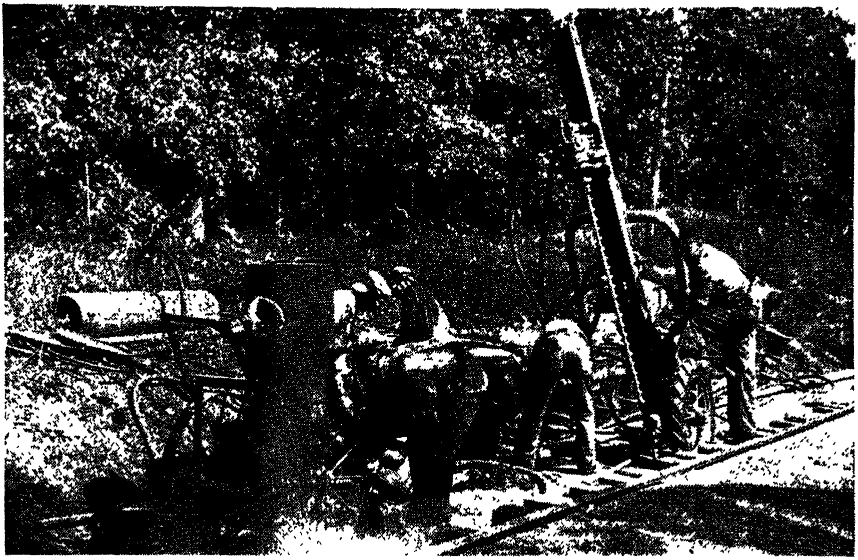


Fig. 11.—A Sand-Filled Blast Hole Gang at Work. The fogged appearance at the sand tank is due to the dust cloud caused by a blast.

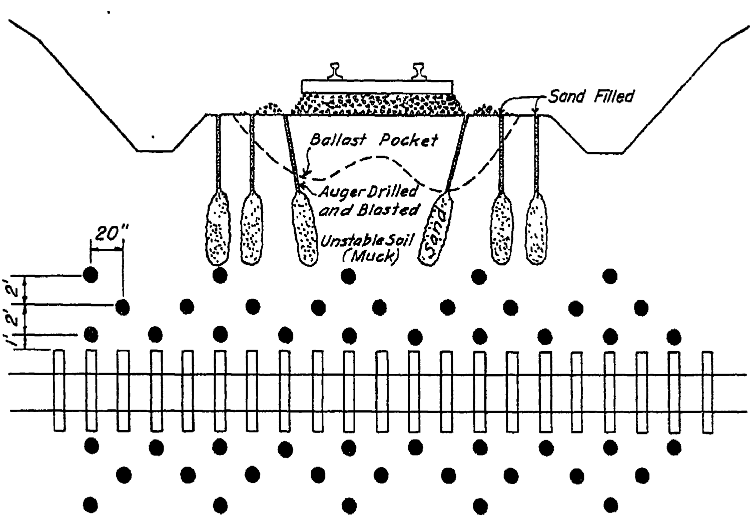


Fig. 12.—Sand-Filled Blast Holes. Typical Treatment for Soft Track in Cuts.

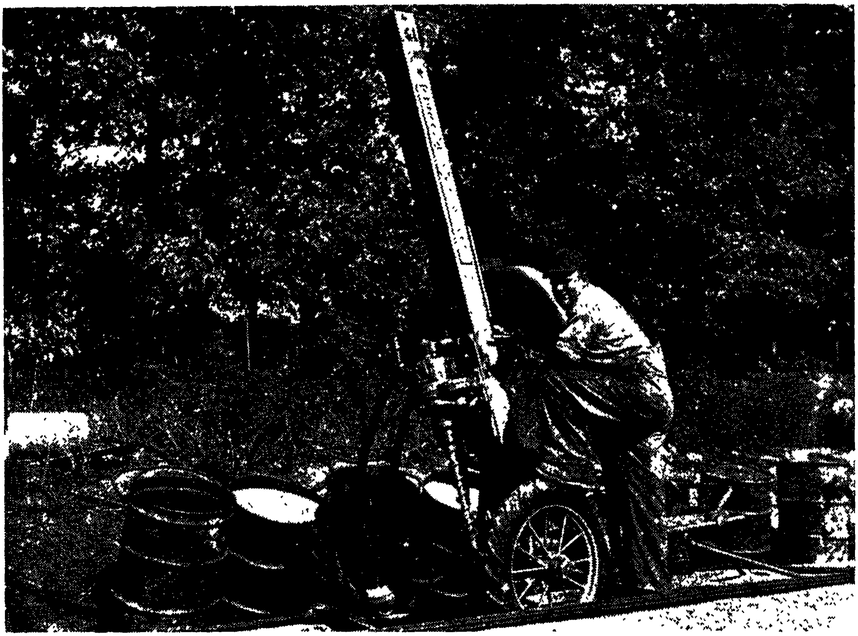


Fig. 10.—An Earth Auger in Operation.

sand by hand with shovels or buckets. By staggering the order of driving, both driving and filling can be done at the same time. At times the spud has been used to compact the sand in the hole after filling.

The sand-pile treatment will raise the track, possibly up to four inches. Provision must be made for run-offs and adequate protection for traffic at all times.

Sand-Filled Blast Holes

1. *General.*—A recent modification of the sand-pile method is the sand-filled blast hole. In this process a two or three-inch spud or auger hole replaces the large spud. A charge of dynamite then blasts a cavity which is filled with sand forced in by compressed air. Each hole is blasted and filled before the next one has been blown. This method has been successful in cut sections and on fills up to 15 ft. in height where the slippage has occurred on a stratum below original ground. The performance record, although very good, is limited to one railroad. Until further investigation, use of the method should be limited to water pockets in cuts and low fills and to failures or slips on the foundation of higher fills. It should be used cautiously if at all on fills founded on slopes. There is also some question as to whether its use in areas of deep frost penetration will prove sufficiently permanent to amortize the cost. Sections now in service, however, have been very successful over a two-year period. The process gives promise of yielding good results for certain conditions of instability.

2. *Equipment.*—A metal spud of approximately three inches in diameter may be driven to produce the hole for blasting. However, a power earth auger mounted on wheels and with a frame support to permit drilling at any angle will prove economical.

of the same magnitude as the maximum repeated load. When surface water was present, the first few loads produced no appreciable deformation, whereas, after a period of loading, the penetration of the pedestal into the sample increased rapidly with the number of applications. For the degrees of compaction achieved in the laboratory, penetrations under these conditions increased indefinitely with the number of applications.

Next, the effects resulting from the presence of ballast on the subgrade were investigated. The tests performed for this purpose are designated as *tests with ballast*. It was found that typical field conditions, including the formation of water pockets, could be duplicated.

Of the various remedial methods developed for soft spots, the most widely used is the injection of cement grout. However, it is not known why grouting is effective or whether present grouting procedures are as efficient as possible. To investigate these matters, several other tests were performed, designated as *tests of cement grouting*. In some of these tests, a layer of cement mortar was placed between the ballast and the simulated subgrade. It was observed that the ballast completely crushed the layer of mortar during the initial period of loading. If the subgrade was not flooded, no permanent beneficial effects of the mortar were observed. On the other hand, when the surface of the sample was flooded, the mortar tended to reduce the penetration even after it had been crushed. The reduction was greater than that associated with the replacement of the mortar with wire mesh having a rigidity comparable to the initial rigidity of the mortar but permitting the free passage of water into the clay.

It has been suggested that the beneficial effects of cement pressure grouting may be due partly to the removal by the grout of moisture from the soil. In addition, it has been suggested that calcium ions released from the cement may alter the properties of the clay by the physico-chemical process of base exchange. A short series of tests was undertaken to investigate the magnitude and characteristics of these effects. For the clays studied, the tests showed that base exchange is not important and that cement mortar does not absorb water from the soil. Rather, with the consistencies of grout used in present practice, the mortar tends to lose moisture, the latter going into the soil when there is no outlet.

The studies described herein indicate a need for further investigation. The program for the immediate future includes the following groups of tests:

1. A continuation of the series with ballast, using extremely low and extremely high initial water contents in the simulated subgrade. These tests should lead to more definite relationships between the deformations corresponding to various initial water contents and strengths.

2. A study of the behavior of a highly plastic clay subgrade. This is desirable because the soils used thus far cover only the lower range of the plasticity which is characteristics of clays that have become unstable in the field.

3. A more thorough investigation of the factors that influence the effectiveness of cement grout, with the object of finding means for improving present grouting practice. The investigation will include a study of various methods of grouting.

Materials

The first progress report contains a description of the properties of one of the materials (designated as material I) used in the present investigation. A second material (II), of greater plasticity, was subsequently included in the program. The Atterberg limits and the results of compaction tests performed on both materials appear in Table 3. The grain-size distribution curve for each material is shown in Fig. 13. This figure

The auger should be equipped with detachable bits of convenient length to permit any depth of drilling. Such equipment is a variation of a quarry wagon drill and is available commercially. Fig. 10 is a view of the earth auger used on one project.

In addition to the auger, a compressor is required to blow the sand into the holes. If the auger is powered by compressed air a compressor capacity greater than 105 cu. ft. per min. will be required for simultaneous operation of the drill and the sand blast. Other equipment required will include a sand blast tank, hoses, a sand drier and blasting apparatus. A sand tank is shown in Fig. 11.

3. *Materials.*—The sand should be coarse and sharp. To flow satisfactorily from the tank through the hose into the cavity it must be completely dried. About 1½ sticks of standard 40-percent dynamite are commonly used, with blasting caps and an electric detonator.

4. *Procedure.*—The severity of the instability will determine the degree of treatment. Fig. 12 shows a typical layout of the blast holes where both sides of the track are treated. For stabilizing water pockets the blast holes should penetrate through the water pocket at least three feet. For the treatment of fills sliding along an underground stratum, the holes should penetrate the stratum by at least one foot. Fig. 11 is a reproduction of a photograph taken during a blast and shows that the surface disturbance is small.

Part III. 1950 Report of a Laboratory Investigation of Roadbed Stabilization

By H. O. Ireland and Emilio Rosenbleuth

Special Research Associate and Research Graduate Assistant University of Illinois

Introduction

This is the second progress report of a laboratory investigation for studying the factors that cause soft spots in roadbeds. The first report appeared in the AREA Proceedings, Vol. 50, 1949.

The investigation is part of the research work of the Engineering Division, AAR. It is being done at the request of the AREA Committee on Roadway and Ballast, by the Engineering Experiment Station of the University of Illinois under the direction of Dr. R. B. Peck.

The main part of the investigation deals with the behavior of a simulated roadbed compacted in a box having a 29¾-in. by 32-in. base and a 12-in. depth. The loading apparatus was described in the first progress report. It produces a pulsating vertical load of which the magnitude and number of applications per minute are comparable to those produced by a freight train traveling at a speed of 60 mph. The load is applied to the simulated roadbed through a pedestal having a base six inches square.

At the outset of the investigation it was necessary to gain insight concerning the behavior of cohesive soils under repeated stresses. This led to a preliminary series of tests, designated as *tests without ballast*. The initial tests of this series were described in the first progress report. To study the effects of the presence of water, the surface of the samples was flooded in a number of tests after a period of loading. The action of the simulated subgrade was essentially different before and after surface water was added. Beforehand, the resistance of the soil was nearly equal to that under a static load

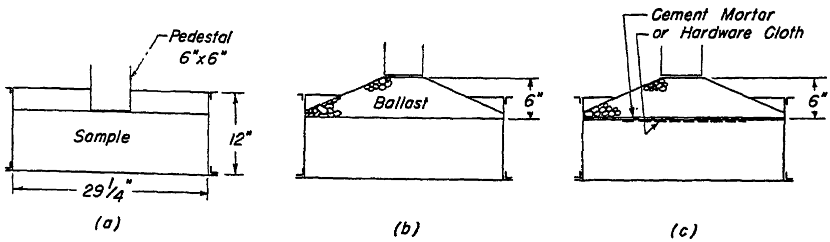


Fig. 14.—Repeated-Loading Samples Ready for Testing.
(a) Tests without Ballast; (b) Tests with Ballast; (c) Tests of Cement Grouting.

Two tests were made on material II to investigate the action of cement grout. (Fig. 14c). For the first, a 3/16-in. layer of mortar was poured on the clay subgrade. Before the mortar hardened, pieces of gravel from the ballast were set into it. The mortar was a mixture of 1 part of cement, 5 of sand, and 1½ of water. It was allowed to harden approximately 24 hours before the test. Testing proceeded as in the series with ballast. For the second test, the layer of mortar was replaced by a wire screen measuring 18 in. by 23 in. and consisting of 4 meshes to the inch.

After the completion of each test in every series, specimens for water-content determination were taken from different parts of the subgrade. Also, in a large number of cases, relatively undisturbed specimens for unconfined compression tests were taken before and after the test.

Profiles of the upper surface of the model subgrade were determined in two mutually perpendicular directions at the following stages: First, before beginning the test or, if ballast was used, before placing the ballast; second, after completing the test and removing any ballast that did not adhere to the sample; and third, after removing all the ballast, including that which penetrated into the subgrade. The heaving and settling of the material, as well as the depth of penetration of the ballast, were determined by means of these profiles.

The materials used in the tests to investigate the drainage and chemical hardening due to cement grouting were the same as those employed for the repeated-loading series. The initial dry densities of the soil were also the same. The samples were 4.6 in. high and 4 in. in diameter. Each sample was cut so as to fit inside a metal can with a clearance of about ⅜ in. This space was filled with mortar as shown in Fig. 15. After three weeks the cans were opened, the mortar broken, and the water content determined at different points within the sample. The liquid and plastic limits were also determined.

Tests without Ballast

Fig. 16 shows several typical time-penetration curves obtained in this series. The values of time are plotted to a semi-logarithmic scale. The material used and the initial water content for each test are indicated in the figure.

Surface water was not added to any sample before the repetitional load had been applied for at least 500 min. Therefore, the behavior of the materials before flooding can be compared at an elapsed time of this magnitude. The results of such comparisons are shown in Fig. 17 in which the penetration of the loading plate is plotted as a function of the water content of the material as placed. A marked increase in penetration occurred at a definite critical intensity of moisture content for each material.

The results of tests performed on undisturbed specimens indicated a definite relationship between the unconfined compressive strength of the materials as placed

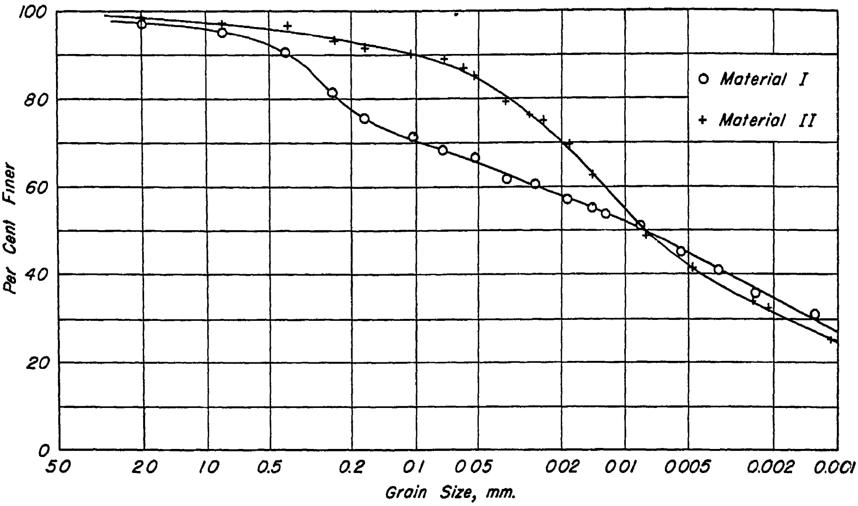


Fig. 13.—Grain Size Distribution.

shows that both materials contain 30 to 35 percent of clay-sized particles (particles smaller than 0.002 mm.).

The simulated ballast is a gravel of subangular particles which contain a fairly large percentage of soft and friable pebbles. Its size ranges from ½-in. to about 2 in.

TABLE 3

Material	*Liquid Limit Percent*	*Plastic Limit Percent*	*Modified Max. Dry Density, lb. per cu. ft.*	*AASHO Test Optimum Water Content Percent*	*Standard Max. Dry Density lb. per cu. ft.*	*Proctor Optimum Water Content Percent*
I	17.9	13.3	126.7	8.8	126.5	11.8
II	49.9	20.0	115.1	14.9	99.8	17.3

Test Procedures

Six tests without ballast were made on material I and seven on material II. The samples were prepared by adding water to the soil in a mixer. Mixing continued until a uniform mass was obtained, whereupon the water content was determined. The mixture was then compacted in the box which contained the simulated subgrade. The compaction was done by dropping a 24¾-lb. ram, 8 in. in diameter, about 180 times on each of three equal layers. The dry densities achieved by this method of compaction were equal to 97 and 96 lb. per cu. ft. for materials I and II, respectively. After every test the material was taken out of the box and used in further tests. During the application of repetitional loads the loading pedestal rested directly upon the simulated subgrade (Fig. 14a).*

Seven tests with ballast were made, all on material II. After the sample was compacted as for the tests without ballast, approximately 100 lb. of ballast were arranged on it in the shape of a truncated cone (Fig. 14b). During the test, the loading pedestal rested on the ballast.

* Test 3A, described in the first progress report, is not included in the present report because the testing procedure was different from that for all other tests.

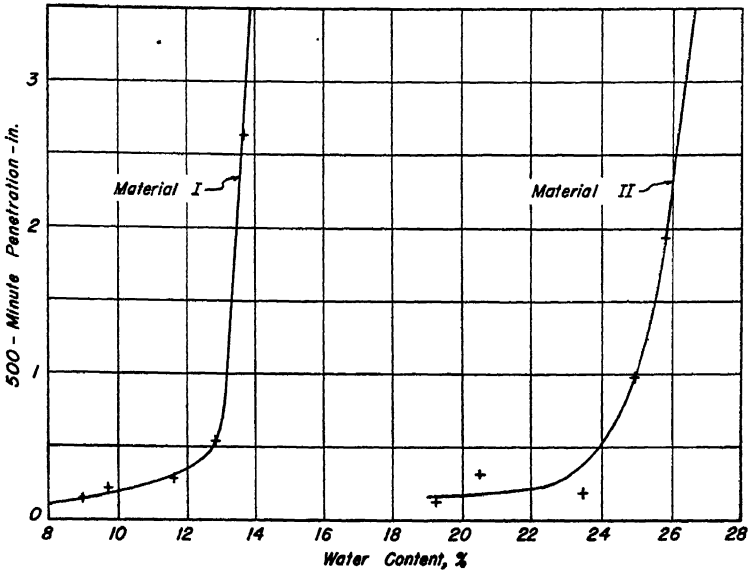


Fig. 17.—Water Content–Penetration Curves. Tests without Ballast.

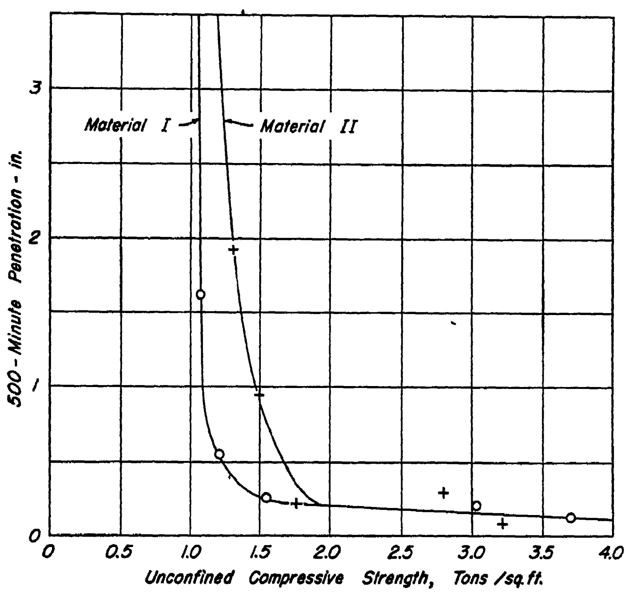


Fig. 18.—Compressive Strength–Penetration Curves. Tests without Ballast.

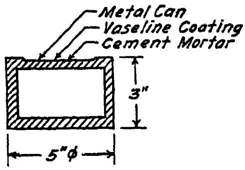


Fig. 15.—Sample for the Study of Drainage or Hardening Due to Cement.

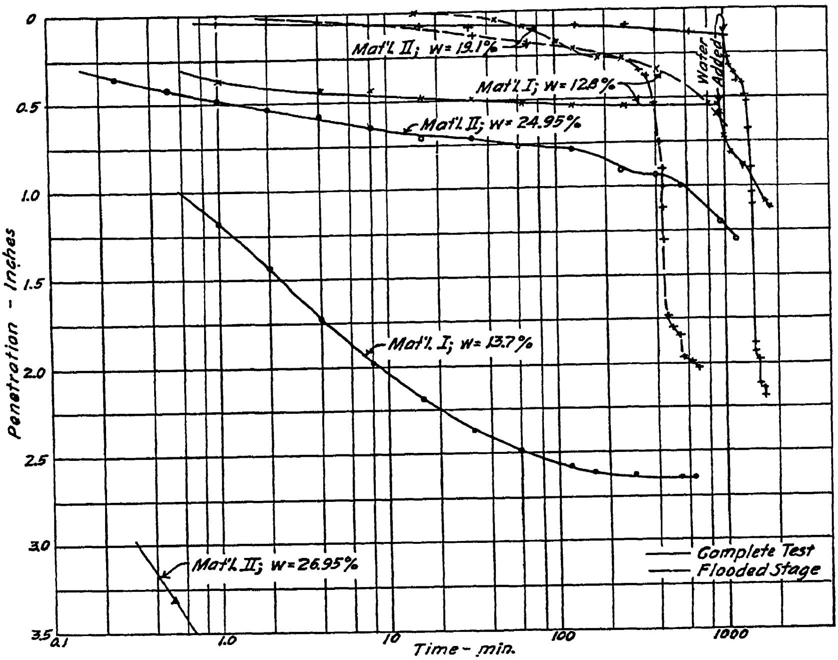


Fig. 16.—Time-Penetration Curve Tests without Ballast.

and the original water content. Fig. 18 is based upon this relationship and upon the data plotted in Fig. 17. Curves I and II represent 500-min. penetrations as functions of the compressive strength for materials I and II, respectively. It may be noted that the penetration increases sharply when the compressive strength becomes equal to a critical value which depends on the material under consideration. According to the results of theoretical bearing-capacity computations, the unconfined compressive strength required to prevent failure under static loading is equal to 1.14 tons per sq. ft. The computations are based on the assumption that no shearing stresses act at the contact between the loading plate and the soil.

Curves similar to those in Fig. 18 were constructed for penetrations corresponding to periods of loading of 0.25, 1, 10 and 100 min. Each curve indicates a limiting compressive strength, but the limiting value decreases with increasing number of repetitions as shown in Fig. 19. The values that appear on the vertical axis of this figure were obtained by dividing the limiting strengths by the theoretical strength of 1.14 tons per sq. ft. The values on the horizontal scale equal the minutes of loading times 229, the number of load repetitions per minute.

Tests with Ballast

A typical sample after testing is shown in the upper view in Fig. 20. The appearance after removal of the loose ballast is shown in the upper view. The subgrade material had an init:al water content of 26.0 percent. The surface was flooded after 510 min. of loading, and the test discontinued at 1012 min. Fig. 21 shows the profile of the subgrade

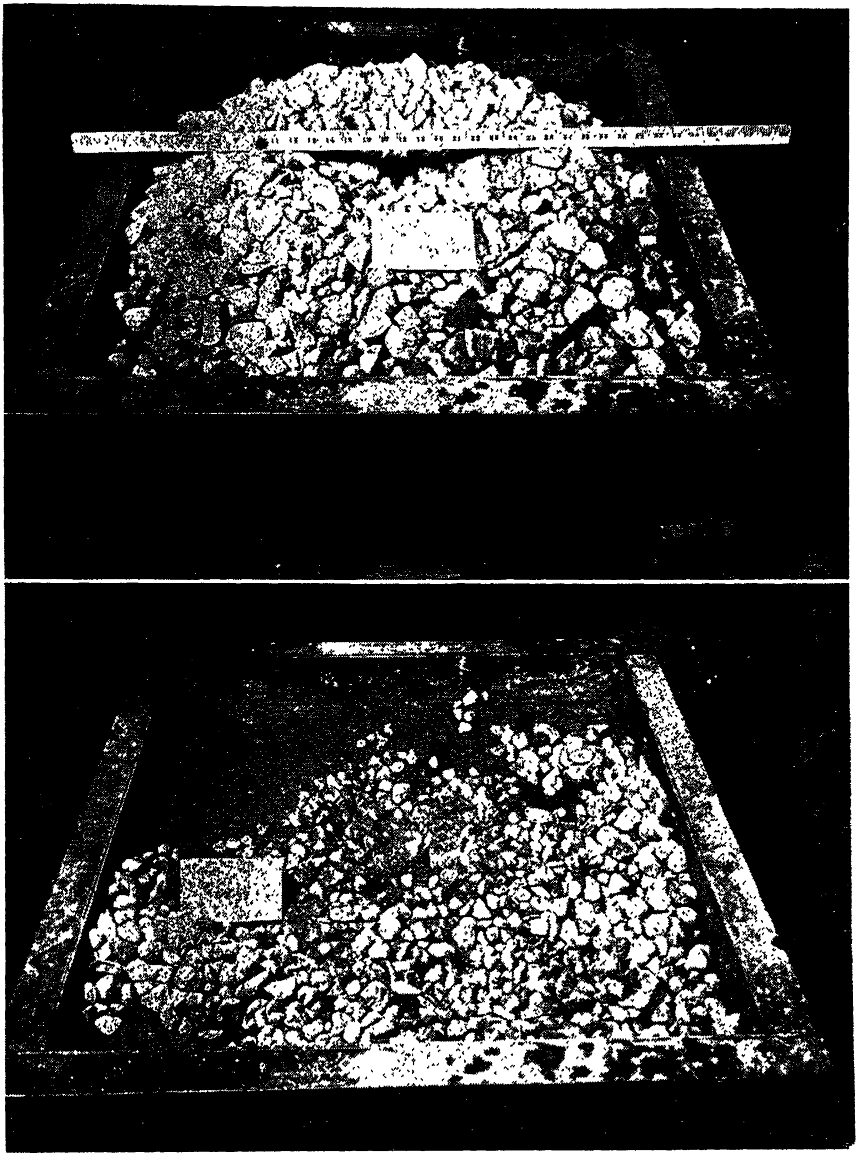


Fig. 20.—Photographs of Samples.

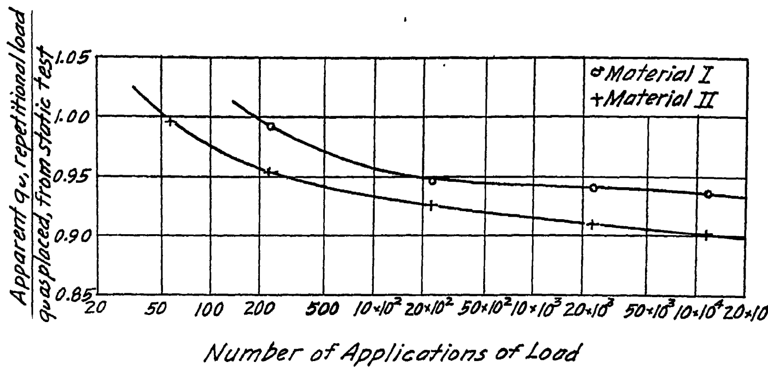


Fig. 19.—Apparent Compressive Strength Tests without Ballast.

It appears that as time elapses, the soil beneath the applied loads undergoes consolidation and water and air are squeezed out. Nevertheless, this effect is of minor consequence because the water content of the soil a few inches below the loading pedestal was found to be only slightly less than the original value.

Surface water was added in three tests on material I and in two on material II. Typical time-penetration curves appear as dash lines in Fig. 16. The phenomena observed in connection with this stage of the tests have already been summarized in the introduction. Very little penetration occurred during the initial seconds or minutes of the flooded stage, even when the samples had soaked for several hours before the repetitional loading began. Obviously, the degree of softening resulting from the penetration of water was much greater after a few minutes of repeated loading than several hours of mere soaking.

The behavior of the simulated subgrades in the flooded stage is probably best interpreted in the following manner:

> Under very small pressures, every clay tends to swell in the presence of free water. The process is usually very slow under static conditions because of the low permeability of cohesive soils. However, when the soil is subjected to a repeated load, the small amount of water it absorbs during the time when the load is practically zero is driven toward the interior of the mass under the action of the next increase in load. Thus, the water progresses downward from the free surface by a pumping process at a much faster rate than under static conditions. The absorption of water results in a considerable loss of shearing resistance in a small volume of soil near the surface, especially in the regions subjected to the highest stresses. As the test proceeds, the shearing strength of the soil in these zones decreases to values equal to the shearing stresses. Hence, localized failures take place. The weakest material is then expelled from under the loading pedestal. A series of such localized failures causes the pedestal to penetrate into regions relatively unaffected by water. The path that must be followed by the water to reach these new regions becomes longer as the test proceeds. Moreover, there is a tendency for some consolidation to take place under the load. Consequently, a longer period of time is required to overcome the resistance to penetration, and a decrease in the rate of penetration after long periods of time is to be expected.

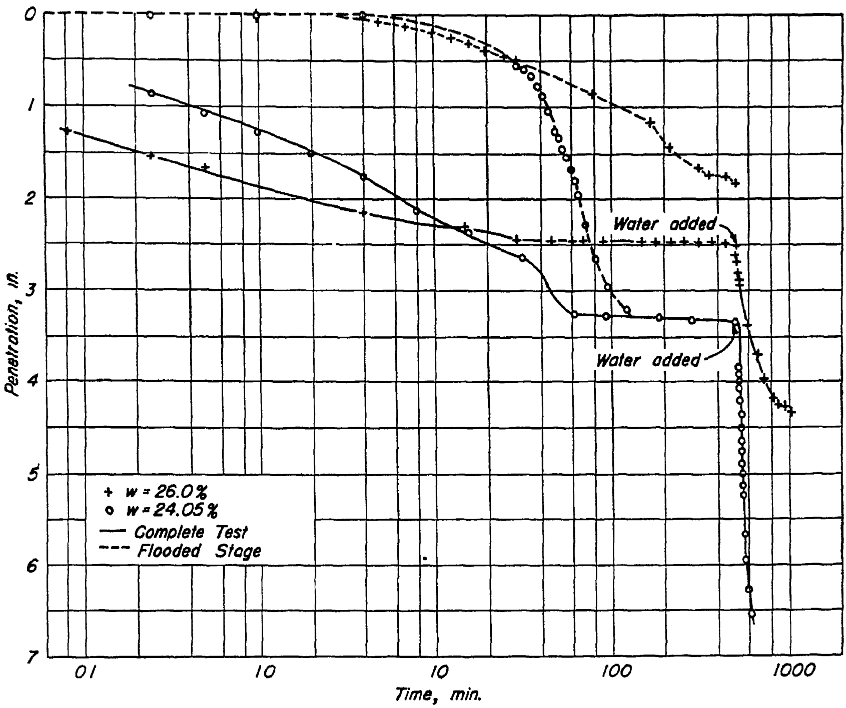


Fig. 23.—Time–Penetration Curves. Tests with Ballast.

The behavior of samples in the tests with ballast was in many respects similar to their behavior when ballast was not used. The main difference in the conditions appears to be that the load acted over a large part of the surface of the sample, but through a number of high concentrations of stress. Where the concentrations existed there was a mixture of soil and ballast. Because of the mixture of ballast with the soil, the water had to traverse a longer path in the flooded stage to reach the inner part of the subgrade. Hence, a longer period of time was required for the first penetrations to develop. This is demonstrated by a comparison of Figs. 16 and 23.

Tests of Cement Grouting

The initial water content for the two tests in this series corresponded to an unconfined compressive strength of about 1.1 ton per sq. ft. This is approximately equal to the water content of one of the samples with ballast. The time-penetration curves for the three tests are plotted in Fig. 12. Curves for the flooded stages appear as dash lines. The strength of the wire mesh was greater than that of the layer of mortar 3/16 in. thick. Although the wire mesh is ductile whereas the mortar is brittle, the difference in penetration before flooding (Fig. 24) was relatively small. In comparison with the results of the corresponding test with ballast only the decrease in penetration in the test with mortar was rather large during the first four minutes of loading. However, after further applications of load, the penetration into the sample with the layer of mortar was larger than in the corresponding test with ballast only.

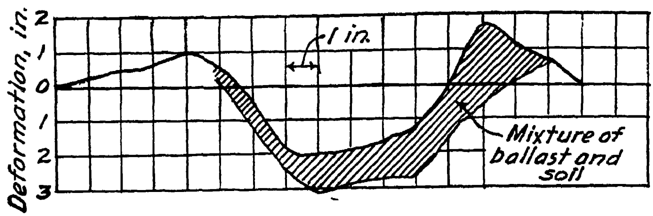


Fig. 21.—Profile After Removal of Ballast. Test with Ballast.

after the test. Especially to be noted in the figure are the lateral bulges or mounds of displaced material, some of which consisted of a mixture of ballast and soil. Such mounds and mixtures of ballast and soil occurred whether the surface had been flooded or not. Fig. 22 shows the distribution of water content in a vertical direction in those samples which were flooded. The uppermost part of the samples had such a large water content that it was sometimes difficult to distinguish between the soil and the pond of water that formed over it.

The time-penetration curves appearing in Fig. 23 to a semi-logarithmic scale are characteristic of those obtained for tests with ballast. The dash lines correspond to the flooded stage.

In the tests with ballast, the measured penetration was equal to the sum of the vertical displacement of the subgrade below the loading plate and the compaction of the ballast. The amount of compaction undergone by the ballast in the first 500 min. was not greatly different for different tests. However, the maximum size of the pebbles in the ballast was quite large as compared to the dimensions of the loading pedestal. As a consequence, no definite correlation such as that shown in Fig. 17 was found between water content and penetration into the samples to which no free water was added. Nevertheless, there was a general increase of penetration with increasing values of initial water content.

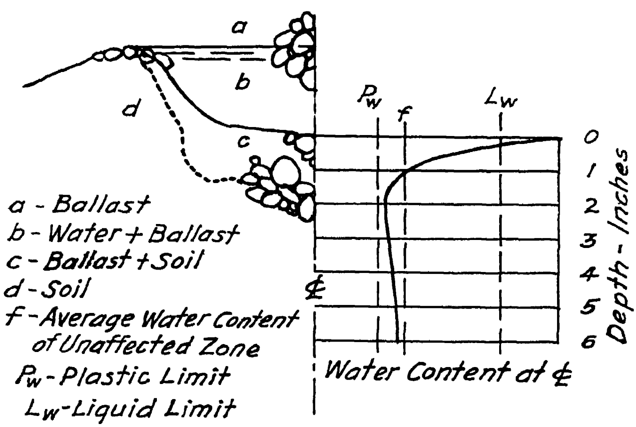


Fig. 22.—Variation of Water Content with Depth. Tests with Ballast.

Conditions were quite different during the flooded stage. The penetration for the test with ballast only was much the greatest, whereas that for the sample covered with a layer of mortar was the least. The curve for this test indicates practically no penetration during the first 50 or 60 min. of loading.

Profiles corresponding to the tests with mortar or wire mesh are shown in Fig. 25. In comparison with the mounds in the tests with ballast only, the small size of those appearing in Fig. 25 is noted. This indicates the beneficial effect of both the mortar and the wire mesh. It seems likely that before the mortar breaks, it serves to eliminate the large concentrations of stress, thus diminishing the rate of penetration. It also seems likely that the mortar in the laboratory test was completely crushed before the first 500 min. of loading. At the beginning of the flooded stage, the disintegrated mortar had already mixed with the upper portion of the clay. This mixture lay immediately beneath the ballast and was directly acted upon by the stress concentrations. It is likely that the properties of this mixture determine to a large extent the rate of penetration of ballast into the soil. Further investigation is needed to ascertain the practical implications of these statements.

In the tests made to investigate the influence of cement on the properties of the clay, it was found that after long contact, the water content of the clay was not smaller but slightly larger in the zones near the mortar, in spite of the fact that the consistency of the mortar used in the tests was somewhat drier than that which is customary in cement pressure-grouting. Moreover, no significant changes occurred in the liquid and plastic limits. Thus it appears that the beneficial effects of grouting are mechanical rather than physico-chemical in nature.

Report on Assignment 6 (b)

Construction and Protection of Roadbed Across Reservoir Areas; Specifications

B. H. Crosland (chairman, section (b)), G. W. Payne, C. S. Robinson.

This is a progress report, presented as information.

Last year your committee presented as information a progress report including a tentative typical roadbed section for construction through reservoir areas. This year your committee has continued studies with a view to getting more specific data to warrant definite recommendations with respect to such factors of design as slope, freeboard, thickness of riprap, etc.

There is now presented for your consideration and comment the following information as a guide in determining proper freeboard, which was referred to as "D" in Fig. 1 of the report submitted and published in the Proceedings, Vol. 49, 1948, page 530.

Of course, many formulas have been developed over the years for determining wave height, upthrust, etc., in relation to fetch, wind velocity and other specific conditions. Unfortunately, none of these formulas specifically meets the conditions confronted here. They were principally developed in connection with harbor or breakwater development involving deep sea waves, long fetches and wide expanse of adjacent waterways.

The Corps of Engineers, United States Department of the Army, has recently arranged to make specific installations on inland reservoirs for the purpose of actually measuring wave heights in proportion to fetches and wind velocities. These studies will

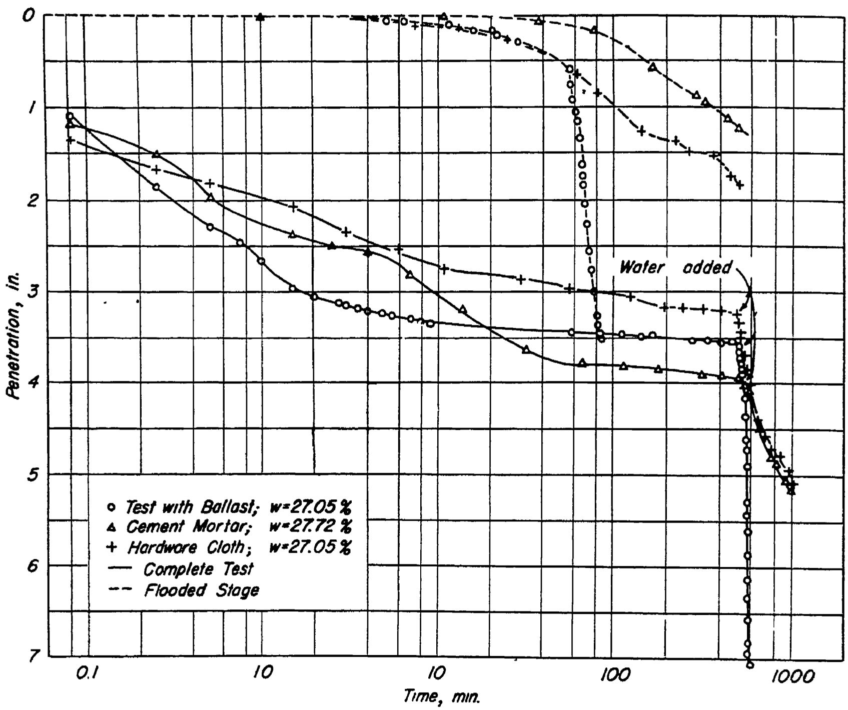


Fig. 24.—Time-Penetration Curves. Investigation of Cement Grouting.

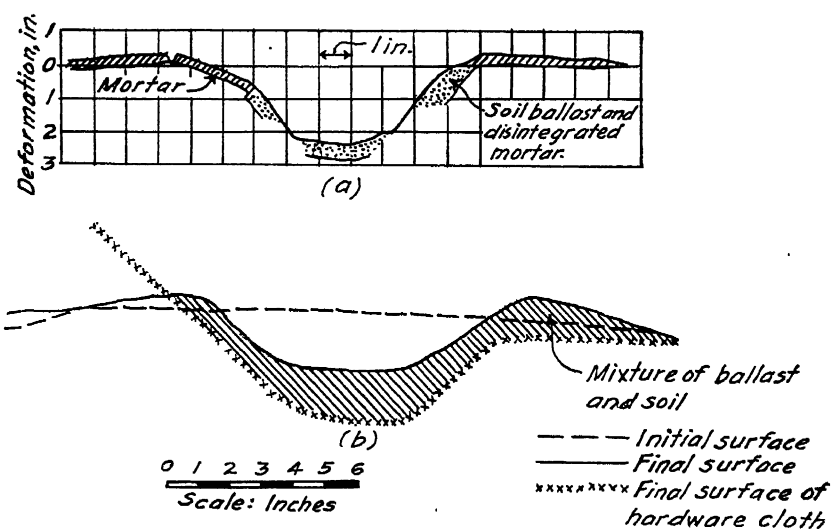


Fig. 25.—Profiles After Removal of Ballast. Investigation of Cement Grouting.

involve observation of wave characteristics at six stations in Lake Okeechobee, four in Fort Peck reservoir and three in Denison reservoir (Lake Texoma). The Corps of Engineers expects to obtain wind data at these stations and at several additional points simultaneously with the automatic readings as to wave heights, both on riprap protected slopes and in free wave movement such as under bridges.

In the meantime your committee has prepared the following data, which are believed to be reasonably accurate and can safely be used as a guide until such time as more definite information is available as a result of the field observations above referred to:

1. Wave heights are dependent upon wind velocity at the surface, duration of the wind, fetch, depth of water and width of reservoir. The height of waves as they approach the fill may be altered by decreasing depth of the water, or by decreasing width of reservoir, but these factors are usually so small that they are not considered in this report. Upon contact with the face of the fill, the effect of the waves is influenced by the angle of the wave train with the fill, slope of fill and texture of the slope surface.

2. The fetch is the distance over which the wind can act. It is sometimes defined as the distance from the leeward shore to the structure under consideration, but actually the effective "fetch" may have a curved path, as the wind effect is continuous along a slightly curved river valley.

3. In determining the required freeboard, the possible wave heights and wave ride-up or upthrust have been given first consideration. The wave ride-up is taken by the Corps of Engineers as 1.4 times the wage height, trough to crest. The multiple 1.5 is sometimes used.

4. A number of formulas have been devised for computing wave heights. Owing to various so-far indeterminate factors involved, these formulas often give rather widely different results.

In arriving at the rather empirical formula shown in Fig. 1, your committee has been temporarily forced to ignore the angle the wave train makes with the fill due to lack of complete data. Based on information available at present, it would appear that no appreciable difference should be made where this angle lies between 90 deg. and 45 deg. Under 45 deg. the coefficient 1.4 may be slightly reduced progressively to a minimum of 1.0 for zero degrees.

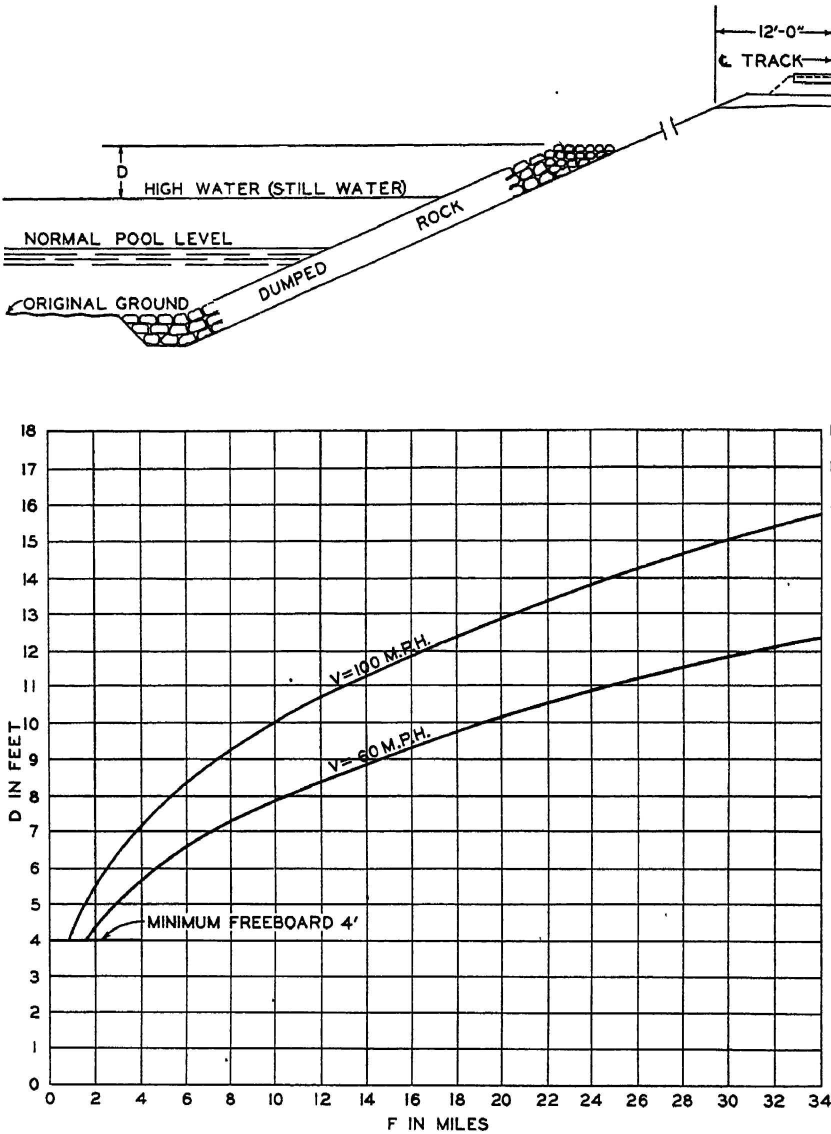
Consideration of the slope of the fill is based on slopes recommended in last year's report, i.e., between 2½:1 and 3½:1, and the texture of the slope surface is taken for dumped riprap.

That portion of the formula involving wave height, trough to crest, is based on a formula proposed by W. P. Creager to the chairman of the ASCE Committee on Study of Slope Protection.

Your committee recommends that in using this formula for unobstructed and relatively level areas a wind velocity of 100 mph. should be assumed; and for more sheltered, mountainous areas, 60 mph. Two curves are indicated in Fig. 1 on that basis.

It is of vital importance that the protective riprap must not be topped by waves. To that end the desired freeboard derived from the formula or curves shown in Fig. 1 is designed to give a factor of safety equivalent to 1/3 of the maximum wave height expected, i.e., two feet in the case of six-foot waves, etc.

It is specifically requested that comparisons of observed actual conditions be checked against this formula and your committee notified as to results, with appropriate suggestions or comments.



$$D = \frac{1.4\,(F^{0.37}\,V^{0.48})}{3}$$

WHERE:–
D = FREEBOARD
F = FETCH (OPEN WATER) IN MILES
V = WIND VELOCITY IN M.P.H.
1.4 = UPTHRUST COEFFICIENT

Fig. 1.—Formula for Freeboard in Terms of Fetch and Wind Velocity.

Report of Committee 24—Cooperative Relations With Universities

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Lem Adams
M. B. Allen
W. S. Autrey
J. B. Babcock
T. A. Blair
Armstrong Chinn
J. B. Clark
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H. O. Sharp
J. F. D. Smith
R. J. Stone
D. W. Tillman
E. C. Vandenburgh
Barton Wheelwright
R. C. White
A. D. Wolff

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managemnts of
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

   Progress report, presented as information .... page 760

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

   Progress report, presented as information .... page 764

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information .... page 765

The Committee on Cooperative Relations with Universities,
S. R. Hursh, *Chairman.*

AREA Bulletin 486, February 1950.

4. The prospect of being away from home a considerable portion of the time.
5. Too many moves; retirement tax too expensive; limited vacations.

Item 1 is probably not too serious, as the returns to the questionnaires indicate clearly that the railroad salaries are about in line with other industries.

Item 2 indicates that in order to encourage individuals who are interested in their future, and are willing to work, the railroads should formulate as definite a plan as practicable for their advancement, and place them in positions of greater responsibility as their ability and capacity for that responsibility is reached.

As to Items 3, 4 and 5, it is thought that the engineering graduates hired by the railroads must be ambitious, industrious, and not too concerned about the hours they may be required to work. Men who leave railroad service for these causes probably do not possess the qualities railroads consider indispensable. It would be far better to eliminate such individuals in the pre-employment stages than to waste their time and the railroads' money in finding it out the hard way.

One university commented as follows:

"Our graduates are definitely disinterested in railroad work; not for reasons of salary, but because of:

"1. Bad personnel practice,
"2. No incentive,
"3. Low standards of engineering work.

"This reputation has developed over the years and become widespread among engineering students, through sons of railroad employees and those who have had vacation experience with the roads, and from present engineering employees whose morale is bad. Pay is a minor factor."

Another wrote:

"You will be also surprised that none of our graduating seniors went into railroad work. We had a few representatives of railroads represented for recruiting on our campus during the past year. Since the railroads have not been visiting us to any extent our seniors are not oriented toward railroad work, and such a condition takes time to remedy. Since there appears to be interest on the part of railroads, we shall begin to work on this."

These remarks indicate a definite need for better liaison and understanding with the schools to counteract false conceptions and to publicize in a positive way the opportunities in railroad employment.

A different view from those quoted above was expressed by one engineering dean whose school had supplied a number of engineering graduates for railroad employment. He wrote:

"Personally I know there is still a good future in railroad work for the young engineer with guts, leadership, brains, who is not afraid of hard work and long hours." He goes on to say that the thing that keeps young men from going with the railroads is the long hours and irregular work and breaking up family life—which is particularly true of the younger "vets," who have already seen little of their wives and children due to service and schooling. Another reason given is a lack of understanding of the true nature of railroad work.

As reported in 1949 there is little to indicate that much has been accomplished on our assignments. By analysis and study of the facts brought out by the questionnaires we should be able to place in the hands of the railroad engineering officers the basic information needed to present the case to their individual managements. The only way

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Managements of:

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

J. B. Akers (chairman, subcommittee), M. B. Allen, J. B. Clark, H. R. Clarke, C. G. Grove, E. M. Hastings, Clark Hungerford, G. A. Kellow, N. W. Kopp, F. J. Lewis, C. H. Mottier, R. B. Rice, R. J. Stone, R. C. White, A. D. Wolff.

In September 1948 questionnaires were sent to a large number of railroads and colleges to develop data on salaries paid to engineering graduates in the employ of railroads and other lines of work, and also other related data. The data given in the returns to these questionnaires were tabulated, but received too late for study and report at the last meeting of the Association.

Replies to Questionnaire No. 1 were received from 32 railroads, and 48 colleges sent in data on Questionnaire No. 2. Copies of the questionnaire as issued, but filled in with a summary of the replies insofar as this could be done, are presented in Exhibit A.

Of the 32 railroads reporting, only 11 interviewed prospects at schools before graduation as a means of determining desirable employees. Nine roads indicated that they employed no graduate engineers except through the initiative of the graduate. The questionnaires covered the last half of 1947 and the first three quarters of 1948. This was a period of scarcity of engineers, and it seems that if other roads needing engineering graduates had adopted the policy of going to the schools they would have been more successful in recruiting men. This indicates little initiative on the part of the railroads generally.

The inference to be drawn from these reports is that there is need for much more active solicitation by railroads for these engineering graduates, in order to fill their present and prospective needs, and if this course were pursued, the roads would be more successful in inducing engineering graduates to enter railroad service.

The replies to Questionnaire No. 2, sent to the colleges, indicate the average starting salary paid by the railroads is in line with, and slightly above, the average paid by industry generally, and the minimum railroad salary is well above the minimum reported for all graduates. From this it seems there is no need at this time for higher average salaries to induce graduates to enter the railroad field.

One very disturbing factor revealed by these statements is the large proportion of men leaving railroad service after being employed only a short time. Of the 1947 graduates, 63 or 30 percent had left the service and of those employed in the 9 months of 1948, 29 or 13 percent had already quit. The turnover seems unduly large. Some of the reasons given were:

1. The ability to earn more money in other lines of endeavor.
2. No definite schedule for advancement, and the prospect of slower advancement than might be anticipated in other fields.
3. The fact that railroad work requires longer hours than are customary in other industries. (Railroads now generally operate on a 5-day, 40-hour week.)

9. Based on your contact with prospective graduates and faculty of colleges and universities what starting salary, in your opinion, is required for the railroads to attract promising graduates?

   $240–$350

10. Would be pleased to receive any comment you might care to offer on related phases of this subject such as why you were not able to employ a sufficient number of graduates, reasons why those you have employed have quit, etc.

    Various.

11. Please give present salary for following positions:

Rodman	$207.00 to $300.00
Instrumentman	$260.00 to $369.33
Junior engineer	$225.00 to $445.00
Assistant engineer	$244.30 to $655.00
Track supervisor	$297.20 to $510.00
Bridge and building supervisor	$330.00 to $482.00
Assistant division engineer	$311.26 to $530.00
Division engineer	$425.00 to $675.00

12. Number of officers and executives who are trained engineers 1594
    Percentage of total—officers and executives ....(Note B)
    (Include all officer personnel—division engineer and above)

13. 1 (a) Number of engineering personnel who will retire within next 5 years 480
    1 (b) Number of engineering personnel who will retire within next 10 years 984
    2 Number of additional engineers required due to promotions (aside from retirements) ....(Note C)

Notes (A) 96 not accounted for.
(B) Percentage cannot be summarized, as some roads included engineering departments only and some all departments.
(C) Replies could not be summarized as no time limit was given.

Questionnaire No. 2, dated September 16, 1948

1. Name of Institution ....48 replies
2. Officer answering questionnaire ....Various
3. Indicate salaries paid (1948) graduates receiving bachelors degrees:

	All Civil Engineering Graduates	*Graduates Employed by Railroads*
Maximum salary	$460*	$410
Minimum salary	$145*	$225
Average salary	$275	$283
Number of graduates on which average is based	2046	49
Total number of graduates in this year's class	5640	68

4. Indicate salary paid each one of this year's graduates in civil engineering who entered railroad work. This is to cover those included in the last column in question 3.

   Not susceptible to summarization.

5. Remarks:

   Various

* Both maximum and minimum were reported by the same school.

to progress the program is for the individual engineering departments to interest themselves in, and impress on management the necessity for developing and carrying out an adequate and cooperative liaison with the colleges.

Conditions have changed since the questionnaires were sent out, and engineering personnel is not now so hard to recruit. This should not be taken as an excuse to drop the development of a program. Rather, this should be seized as an opportunity to foster closer relations with the engineering schools to develop practices which will insure the railroads getting men from "the cream of the crop."

Appendix A

Questionnaire No. 1, dated September 16, 1948

1. Name of railroad ....32 replies
2. Officer answering questionnaire ....chief engineer
3. Indicate starting rates, titles and number of graduates* hired in years 1947 and 1948.

		Year 1947		*Jan. 1, 1948 to Date*	
Starting Title	*Starting Rate*	*Number Hired*	*Number Remaining in Service*	*Number Hired*	*Number Remaining in Service*
Various	$198.60 to $460.00	211	148	227	198

4. Indicate number hired since January 1, 1947 classified under the following methods of initiating contacts with graduates:
   (a) Railroad representative interviewing prospect at school 117
   (b) Faculty member acting as intermediary 69
   (c) Application initiated by graduate 135
   (d) Any other methods (name methods and number hired under each method) ....(Note A) 21
5. Do you have a program for pregraduation training through:
   (a) Summer vacation employment 13
   (b) Arrangement with one or more engineering schools for alternating periods of schooling and on-the-job training (often referred to as the "Co-op Plan") 10
6. Do you use any sort of aptitude test to determine whether an applicant is temperamentally fitted for railroad work? 1
7. Do you have a definite schedule for advancing newly employed graduates, and if so, what is the period of each advancement and the increase in salary? If the advancement involves a change in title please so state.

   Seven roads had definite schedule, and five said this involved change in title. Replies to other questions could not be summarized.
8. Have you been able to secure enough graduates at the rates you paid in 1947 and 1948 to meet your requirements?

   Seven railroads said "yes."

* The term graduates as used in this questionnaire means recent graduates with not more than one year's experience since graduation from a university or technical college of recognized equivalent standing.

of the Louisville & Nashville Railroad before a civil engineering group at Alabama Polytechnic Institute; a talk by Past President C. H. Mottier before a student group at Iowa State College; and a talk by President F. S. Schwinn on the subject of Opportunities for Engineers in the Railroad Industry, before an engineering group at the Louisiana State University.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

O. W. Eshbach (chairman, subcommittee), Lem Adams, J. B. Babcock, Armstrong Chinn, P. O. Ferris, C. G. Grove, W. H. Huffman, A. V. Johnston, W. S. Kerr, R. B. Kittredge, T. R. Klingel, A. A. Miller, R. C. Nissen, L. M. Ogilvie, W. A. Oliver, E. C. Vandenburgh.

This is a progress report presented as information.

Following last year's report on vacation and cooperative employment in the post-war period, the committee attempted to determine the attitude of students who had benefited from vacation experience with the several railroads. With the cooperation of the railroads who make a practice of employing engineering students during the vacation period, the names and college associations of these students were obtained. Approximately 12 railway companies regularly hire engineering students for vacation or cooperative work.

The following railroads made reports showing the employment of 97 students from 44 engineering schools:

Atlantic Coast Line Railroad
Burlington Lines
Chicago and North Western Railway System
Denver and Rio Grande Western Railroad
Illinois Central Railroad
Louisville & Nashville Railroad
Missouri Pacific Railroad
New York Central System
Norfolk and Western Railway
Pennsylvania Railroad
Southern Pacific Company
Southern Railway System

Each of the railway companies furnished the names of the students and the colleges in which they were enrolled. The deans of the institutions were furnished the list of the students in their schools who had been employed by railway companies during the summer and were asked to interview the students to obtain their reactions to their work. Up to January 1, 18 reports were received, including 32 comments, which were divided into favorable and unfavorable classifications without identifying the company, student, or college. These comments form an appendix to this report. They have been distributed to all members of Committee 24 and to the schools which furnished the material for this compilation.

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure

By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

R. P. Davis (chairman, subcommittee), L. L. Adams, W. S. Autrey, T. A. Blair, B. B. Lewis, H. S. Loeffler, E. E. Mayo, C. T. Morris, J. E. Perry, J. A. Rust, W. C. Sadler, H. O. Sharp, J. F. D. Smith, D. W. Tilman, Barton Wheelwright.

This progress report is presented as information.

The main activity of this subcommittee continues to be along the lines of promoting an interest in railroad work as a career by arranging visits to engineering schools for the purpose of giving talks before student groups.

As this kind of work is most effectively done by individuals and not by group action, this subcommittee has been enlarged since last year from 8 members to 15 members. As now constituted it contains 8 railroad and 7 college representatives. The geographical distribution extends from Montreal, Que., to Amarillo, Tex., and San Francisco, Calif., and from St. Paul, Minn., to Greenville, S. C. Among the colleges represented on the subcommittee are Cornell University, Iowa State College, Ohio State University, Purdue University, Rensselaer Polytechnic Institute, University of Michigan and West Virginia University.

In order to get members of the Association, in addition to those of Committee 24, more active in promoting our objectives, Chairman S. R. Hursh wrote a letter under date of April 15, 1949, to the chairmen of all standing committees of the Association, which reads in part as follows:

> I think all of you fully appreciate the difficulties of Committee 24 and the problem we are having in selling the railroad industry to the universities. I do feel, however, that much progress has been made, but there is still a lot to be done.
>
> It occurred to me at a meeting of all the chairmen in Chicago last Tuesday that you could be of great benefit if you would request the members of your respective committees, whenever they have an opportunity, to visit a college or university, to give some talk or address before the student chapter of the ASCE or any other student group. They would thus seize the opportunity to sell the railroad industry and the opportunities available for young graduate engineers.

That this appeal by Mr. Hurst was an effective one is borne out by letters received by the subcommittee. A letter from H. F. Fifield of the Boston & Maine Railroad explained how his road has been successful in securing young graduates from various New England colleges by the establishment of training courses.

Among other excellent contacts between the railroads and the colleges were the following: An address by J. W. Wheeler, executive assistant of the Burlington Lines, on the subject of Career Opportunities in Rail Transportation at the Career Conference sponsored by the University of Denver; a paper by C. G. Grove of the Pennsylvania Railroad entitled Maintenance Engineering as a Profession and presented before the Job Opportunities Conference at the University of Wisconsin; an address by L. L. Adams

13. The most interesting feature of railroad work is in construction of warehouses, water tanks, crossings, etc. The railroad engineers are the inspecting party and they do all of the layout work for the contractor. The engineer, since he is on a salary, must work whenever the contractor is working and without overtime. Incidentally the labor foreman on the job usually makes much more than the lowly inspector-engineer who is nearly worked to death trying to do the layout work, concrete design, and still see that the contractor is building according to specifications.

14. To my surprise each boy said he was very well satisfied with the type of experience he obtained and the treatment that was accorded him by the railroad company. All but one would return to the railroad for which he worked last summer. The single exception wished to work on another railroad which he thought offered more opportunity than the one with whom he was employed. All stated that they thought the opportunities for graduate engineers in the railroad organization were great, and they recommended that more of our graduates consider that field of employment.

15. The two boys are seniors in the School of Engineering. Both were so delighted with the work that they hope to get permanent positions with the railroad after they graduate in June. Following are some of the comments the boys made to me concerning their work:

    1. Type of jobs varied sufficiently to give substantial range of experience.
    2. Supervisors and all fellow employees very cooperative and helpful.
    3. Working conditions excellent.
    4. Amazed at the safety precautions taken by the railroad.
    5. Vacation experience helpful in deciding field of work after graduation.

    I may add that these are the type of boys who can be depended upon to do a good job wherever they are placed. They were very enthusiastic and talked to me at some length regarding their experience.

16. On his cooperative work, however, he has been in the civil engineering department and is very well satisfied with the work, both as to the personnel with whom he associates and as to the degree of responsibility he is allowed, and the type of work he is given. He states that, judging from his conversation with other co-operative students, he is given a great deal more freedom and opportunities to do things on his own and display initiative than most of the co-operative students.

17. I have been employed in the engineering department for the past two summers. The work was very enjoyable and very helpful in giving me some experience. The system is large, but everywhere on it the people are very nice and friendly. I think the railroad is a good concern to work for.

18. I was employed as a rodman from June 10 through September 15. I found this work much to my liking in that it was very interesting and highly instructive. It has been my wish to go into railway engineering on completion of my college work, and this summer employment has only strengthened this desire. As for the work, I think that it has many possibilities for a young man beginning a career in engineering.

19. Concerning my working summers for railroads, I enjoyed the work quite a bit as I am interested in railroading and plan to enter it after my graduation. I found the work extremely interesting and directly in line with my training as a civil engineer.

20. He is very much pleased with his work with the railway. His background fits him especially for this type of work. His father has been with the railway for many years.

It is gratifying to note that, in contrast to the many criticisms both from colleges and engineering students, which have been received by the committee in the past, this report is exceptionally favorable. Twenty-seven of the remarks as reported by the deans were decidedly complimentary. Only five could be classified as unfavorable. In both the letters from the deans and the comments, some of which were quite lengthy, there is definite evidence to support the view that one of the most effective means of informing and interesting students and faculty members in advantages offered by the railroads is to employ them so that they may see at first hand the environemnt in which they will work, the nature of the work, and the opportunities presented.

It is unfortunate that no mention was made in any of these reports of the employment of teachers of engineering. It is hoped that from time to time railroads may have the opportunity, and see fit, to invite faculty members to work with them during summer vacations.

Comments of Engineering Students on Employment with the Railroads, Summer, 1949

1. Mr. .... is well satisfied with the experience gained in his railroad employment and with conditions on the job.
2. Mr. .... is equally satisfied with the job and the experience gained. At present he is on the job and has indicated an interest in full-time employment with the company after graduation.
3. This was the student's second summer of work for the railroad. He did drafting and design, especially on transmission crossing design. He believes the work fitted in with his education program. It was not routine or monotonous but very interesting. He was very enthusiastic about the work and hoped he could repeat again next summer.
4. Has been on survey parties, done drafting and design. Past summer most of time on design of grade crossings. Believes emphatically that experience has helped him with his educational program. None of the work was routine or monotonous. He plans to go with the railroad on graduation.
5. Very much interested in work and thought it fitted in with his educational program.
6. Has been in engineering department on surveying work, weed control, and testing equipment. Firmly believes his experience with railroad and college work fit in together closely. He is planning to return to railroad on graduation.
7. Work has been general survey and construction. It was not routine and he enjoyed it. Experience did not fit too closely with any of his educational program. Not sure that he wants to go back with railroad.
8. Employed in the engineering office doing drafting mostly. Believes experience helpful in educational program, not at all routine. Does not plan to go with railroad.
9. All of work very interesting and helpful with educational program. Hopes to go with railroad when he graduates in June if he can get into engineering and design work.
10. Believes all of his experiences with railroad very helpful in his educational program. Through these experiences he was able to make up his mind that he wanted to go into railroading.
11. Believes experience fits in with educational program because he wants to go with railroad on graduation. Hopes to work next summer with railroad.
12. By way of summary I should like to say that I thoroughly enjoyed my summer employment with the railway company and if I could obtain a reasonable position I would seek permanent employment with it upon being graduated from college.

to obtain an education, but I fail to see why a professional man with a sound education is anything but an asset to a large company, assuming that he be an average individual who will exert himself toward the proper ends. Do not misinterpret my complaint—I do not think that the company employees are underpaid The fault that I am pointing out is the meager positions offered by the company to college men. I cannot make a definite assertion along these lines because I am not certain what offers the company makes, if any, to college graduates. However, I feel confident to state that in the engineering department the highest rating offered is that of a rodman, if that high. This rating pays a reasonable salary, but I cannot say that it lives up to my expectations nor those of my classmates. Of course, much of this is determined by a complicated economic system known as "supply and demand" which is beyond the scope of this writing. Despite the fact, I refuse to believe that, when the situations necessitate the employing of college graduates, the company cannot meet the situations with adequate offers.

3. One glaring disadvantage of railroad work is that the work is restricted. In other words, if you are laid off after twenty years' service, the experience you have had will not be of value in getting another job except in railroad work.

4. In reply to your letter of November 10, 1949, you are informed that two of the three students named have been interviewed. The third is not available to us. One is a student in architecture and the other a civil engineer.

   Both reported that the pay was good for student's summer work and that the experience they gained was very valuable. They both had contact with and were supervised by an experienced man. Each student stated that he did not intend to work for the company after graduation because the future is not bright for promotion; the work is standardized and of a limited, routine nature; and one remains for long terms at the same grade. The contact with company personnel was very agreeable, pleasant, and friendly.

5. Both men were interviewed separately in my office. From these interviews, I gained the following impressions as to their reactions to railroad employment for civil engineers:

   (1) The pay was very good.

   (2) Both boys enjoyed their experiences, but one felt that his responsibilities were limited and that he was not permitted to demonstrate his capabilities in more advanced duties.

   (3) Both boys felt that they were treated very well by the railroad employees with whom they were associated.

   (4) I questioned both about employment with railroads after graduation. Neither has definitely decided on continuing in railroad work. The objection of one was that advancement in railroad work is limited too much by seniority. The other objected more to the frequent moving of one's family which is necessary during the first several years of railway employment.

21. Mr. .... was particularly enthusiastic concerning the work. He states that the job was different every day. Both young men enjoyed working for the railroad Each one said he would like to make a career with the railroad. I understand that both boys are being considered by the railroad for permanent employment after graduation.

22. In reply to your letter dated November 9, I am glad to be able to tell you that ...., who worked last summer for the railroad, was very enthusiastic about that experience and considers that he was given a very valuable opportunity to learn what railroad engineering really is. He hopes and expects to secure employment with the railroad after graduation.

23. Mr. .... is now a senior civil engineer. He has informed me that he thoroughly enjoyed his work with the railway and was particularly impressed with the interest shown in him as a prospective employee. I think it may be said that in this case the railroad officials made an effort to impress this young man with the importance of railroad engineering and it is likely that he will return to their services upon graduation.

24. All three men stated that they were glad that they had taken this kind of work and feel that what they learned is helping them with their college courses.

25. I had an opportunity to speak to Mr. .... regarding his employment with the railroad the past two summers and he felt that he had gotten some experience out of his work even though he was employed as a laborer. He is interested in railroad work and expressed a willingness to start at the bottom and get as much experience as possible. Under the circumstances he indicated that the summer employment was satisfactory. If he is given an opportunity to go with the railroad upon graduation next June, I feel certain that he will accept such an offer.

26. All of his work has been in the office of the engineer of tests of the maintenance of way department. From minor responsibilities at the start of his experience, he has recently had quite a valuable degree of responsibility in the testing of rail sections, both in the laboratory and in track. As a result of these tests, he tells me that the 131-lb. rail section has been modified by introducing a larger fillet between the head and web of the rail and that this modified section has now been adopted by the American Railway Engineering Association. He has also done work on heavy rail sections up to the special 155-lb. section.

27. Mr. .... was very much pleased with the employment; he said that he was able to learn a lot within the limitations of his work. He was a rodman on a survey party and did have an opportunity to do some office work. The work, he said, covered figuring cuts and fills, running levels, estimating, etc., etc. I asked him if the railroad company seemed to be interested in his kind of employee and he said they certainly were and treated the boys fine. He thought that most of the men in his category would have reactions similar to his.

Unfavorable

1. Most of time spent as a draftsman, and felt that work was routine and of little value to him educationally.

2. Next on the list of important considerations appears the question of wages, or salaries, as the case may be. For this part I can offer little praise. Perhaps being a student of a professional field has led me to expect too much from the toils set forth

PROCEEDINGS

Program

Forty-Ninth Annual Meeting

Palmer House, Chicago

Tuesday, March 14, 1950

Morning Session—Grand Ballroom—9:45 to 12:30

Address of President, F. S. Schwinn, Assistant Chief Engineer, Missouri Pacific Lines, Houston, 1, Tex.

Report of the Secretary and Treasurer, by W. S. Lacher

Address—The Public Should Be Informed, by J. H. Aydelott, Vice-President, AAR

Presentation of Honorary Membership to E. M. Hastings

Reports of Committees	Bulletin Numbers
13—Water Service and Sanitation	483
9—Highways	483
24—Cooperative Relations with Universities	486

Afternoon Session—Grand Ballroom—2:00 to 4:00

Reports of Committees	
20—Uniform General Contract Forms	483
6—Buildings	484
11—Records and Accounts	485
16—Economics of Railway Location and Operation	483

Adjournment to visit the AAR Research Laboratory

PROCEEDINGS

Running Report of the Annual Meeting of the American Railway Engineering Association, March 14–16, 1950, Palmer House, Chicago, Including Abstracts of All Discussion, All Formal Action on Committee Presentations, Specific Papers and Addresses Presented in Connection with Committee Reports, and Other Official Business of the Association

The opening session of the forty-ninth annual meeting convened at 9:50 a.m., President F. S. Schwinn* presiding.

President Schwinn: The meeting will kindly come to order. This is the 49th annual meeting of the American Railway Engineering Association, and the concurrent session of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads.

May I request that all the past presidents in attendance kindly take places at my right on the platform. Will the current vice presidents, directors, secretary and treasurer take places on my left.

(The past presidents and officers of the Association came to the platform and were introduced to the convention. The past presidents included C. H. Mottier, vice president and chief engineer, Illinois Central Railroad, H. R. Clarke, chief engineer, Burlington Lines; J. B. Akers, chief engineer, Southern Railway System; A. R. Wilson, engineer bridges and buildings, Pennsylvania Railroad (retired) ; and A. A. Miller, chief engineer maintenance of way, Missouri Pacific Railroad (retired).)

President Schwinn: The first order of business is the reading of the minutes of the last annual meeting. These minutes have been printed and a copy has been furnished to each member. We will dispense with the reading of the minutes unless I hear an objection. Hearing no objection, I declare the minutes approved as printed.

In accordance with past procedure, and in conformity with the provisions of the constitution, the next order of business is the President's address.

Address of President F. S. Schwinn

Annually it becomes the duty and privilege of some man whom you previously selected, to stand before you and talk to you on what might be designated as the "state of the nation." These "state of the nation" talks may not constitute easy tasks, neither should I qualify them as hard tasks. Quite correctly, I can describe them as very pleasant tasks. I will add that the pleasure is enhanced many times by the gracious presence of the women. We may take pardonable pride in our accomplishments but we may well remember the help we have received from our wives and mothers. To quote Victor Hugo: "Men have sight; women insight." Today I will attempt a very restricted sight into our immediate future as I do not dare look further. I can justify my reluctance to look far by quoting from the Bible where we may read in both Testaments: "your old men shall dream dreams, your young men shall see visions."

* Assistant Chief Engineer, Missouri Pacific Lines.

Wednesday, March 15, 1950

Morning Session—Red Lacquer Room—9:00 to 12:00

Reports of Committees — Bulletin Numbers

Committee	Bulletin Numbers
27—Maintenance of Way Work Equipment	484
22—Economics of Railway Labor	484
3—Ties	484
17—Wood Preservation	484
1—Roadway and Ballast	486

ASSOCIATION LUNCHEON, 12:00 NOON

Announcement of Results of Election of Officers

Address—The Rosy Road to Ruin, by W. G. Vollmer, President, Texas & Pacific Railway

Afternoon Session—Red Lacquer Room—2:30 to 5:00

Reports of Committees

Committee	Bulletin Numbers
14—Yards and Terminals	483
4—Rail	486
5—Track	486

Thursday, March 16, 1950

Morning Session—Grand Ballroom—9:00 to 12:30

Reports of Committees — Bulletin Numbers

Committee	Bulletin Numbers
7—Wood Bridges and Trestles	485
28—Clearances	484
29—Waterproofing	484
30—Impact and Bridge Stresses	484
8—Masonry	485
15—Iron and Steel Structures	485

Closing Business

Installation of Officers

Adjournment

serious heed to competitive transportation activities with the objective of presenting a helpful answer, either independently or in cooperation with another group, to some phase of that competition. You may question this suggestion, but there are many angles to the competitive situation requiring thorough study in which we can participate. Only one of these would be the development of new or improved ways and means by which the movement of traffic through terminals could be expedited. We may rest assured that the importance of and the responsibilities placed upon our committees will continue to grow. The committees will always be the agency supplying the breath of life to our Association—continuing to make it the living instrumentality for the betterment of the railroad industry.

Better Planning of Our Program

As the vista of our second half century unfolds, we sense other pending changes demanding recognition. The conduct of your annual meetings has given your Board of Direction much concern. No doubt you have noted and been impressed by the marked reduction in the amount of discussion brought forth by committee reports presented during recent years. I will not burden you by recounting the several reasons given for this change. I know the change is not resulting from any lack of concern and I also know that you understand such discussion is highly desirable and always will be well received as it tends to improve the interest in these sessions and the quality of their products. During our fiftieth anniversary sessions, the interest factor was greatly improved by including in the program a number of timely, entertaining and challenging addresses. Because of the occasion those addresses were most appropriate, but we must never lose sight of the fact that our Association's reputation stands upon the work of our committees. I believe you will agree that the program at the annual meeting should consist primarily of the presentation of committee reports. With this in mind, the committees have given much thought and effort toward bettering their presentations this year by the inclusion of short talks relating to their special fields of endeavor. These talks are designed to be of interest value to all members and to the industry generally. The speakers will undertake the giving of that little added something the French descendents down in Louisiana delight in calling "lagniappe." Your Board of Direction looks forward with considerable pleasure to your reception of these talks and the comments or discussion the talks may engender.

Speaking of the committees directs attention to the marked organizational change made during the past two years through an increase in personnel. The change was considered desirable because of the pronounced increase in Association membership, and was made for the purpose of attaining two objectives: to satisfy the demand for places on the committees resulting from the enthusiastic interest of new members, and to make the committee personnel more representative of the conditions and thought encountered over the entire North American continent. It is too early to determine whether this increase in personnel has had the wished for and beneficial effect of improving committee reports. It has increased the volume of work in the office of the secretary and it has placed a greater responsibility upon each committee chairman. There is the resulting possibility that the chairman must devote time to added paper work which might be directed to the improvement of the quality and character of committee reports. While I have no suggestions to offer at this time, I wish to point out that we are still in the experimental stage with respect to committees embracing and requiring the active participation of approximately one-third of our membership.

One year ago, Past-President Mottier said to me: "Mr. Schwinn, you are now given the honor to draw back the curtain and play the first act in the second 50 years of the life of this Association." The reference to drawing back the curtain might have carried with it the implication that an entirely new vista would be unfolded. The vista was not a new one but it changed very materially during the year now closing. It changed rapidly and is continuing to change rapidly. In the coming years it may change even more rapidly. Although we may feel that we are well launched upon the Association's second half century, we cannot foretell the extent to which it will differ from the first half. We cannot anticipate its peculiarities or characteristics, its scope or attending responsibilities. We know all these will be greater or broader and more compelling. We may rest assured the future will be more exacting and more demanding and will require our work to be carried to a higher degree of refinement. In addition to recognizing these ever present changes entering our vista with their new problems, we must be alert to every need for modifications or revisions of our practices and to those newly discovered developments affecting conceptions which we may have considered as final, as finished products laid away in the deep freeze. It is well that we meet here each year to question and weigh our past performances, to acknowledge that which lies before us and to take stock of our ability to meet the issues successfully.

The Significance of Research

I believe the all-embracing activity, the all-encompassing agency which we so easily refer to as research must take an increasingly large part in the moulding of this Association's future recommendations. During the earlier years, our recommended practices usually were developed from the consensus of those who actually participated in the committee work and generally represented their combined experience and observation. Greater use of research during the more recent past has brought about a noticeable change in that practice. More and more of the material going into our Manual is being determined from the results of laboratory and field investigations carried on under scientific control. We may expect this trend to continue. And with this increasing use of research, the part which our committees will take necessarily must differ from that of the past. Upon the committees must fall the obligation of inaugurating the required research. Theirs will be the duty to sense and weigh the need, to outline the problems and objectives and to evaluate the expected results in terms that will warrant undertaking and financing the needed research in their respective fields of study and interest. Committees will have the further duty of condensing and summarizing research reports and of interpreting the results of research in such a manner that the benefits may be made readily applicable to the railroads, either generally or under particular conditions and requirements. At the same time, our committees will find it necessary to be cooperatively critical of research. They will want to assure themselves that the finally developed recommendations are based upon investigations conducted under conditions truly representative of those found in actual service and that they are not designed to support some earlier established practices nor to confirm any preconceived ideas.

So we will find, even with the expanding assistance from and greater dependence upon research, there will be much for the committees to perform in the conversion of those research findings into recommendations which may be readily understood and easily applied by the busy railroad officer. However, I must not leave with you the erroneous impression that all committee work will be of a nature requiring scientific research. We will always have with us the less scientific but equally important economic problems for our analysis, clarification and solution. Each of our committees may well consider itself as a group of railroad economists. Each and every committee may give

In the matter of finances, we find that receipts for the year exceeded disbursements about $5000, but assets increased only about $1000. The answer here lies in the fact that we are rapidly depleting our inventory of Manuals, this inventory loss being converted into cash. The fact that the Association's assets show such a small increase is indicative of a presently correct level of annual dues. In the opinion of your Board of Direction, the net showing for the year represents a very satisfactory result when viewed in the light of the many uncertainties accompanying the continuing upward trend of cost. But with a continuing depletion of stock, we must anticipate the necessity of a complete reprinting of the Manual within the next three years. As the present loose-leaf form has been in use over 17 years, we may also anticipate the need of a drastic overhauling of the contents to place them in proper condition for use in the reprinted Manual. This revision of their respective chapter responsibilities will place much additional work on the shoulders of the committees. As may be readily understood, it will cause a heavy added load to fall upon the secretary's staff. And it will also necessitate the reconversion of a substantial amount of the Association's assets from cash to Manual inventory. I mention this part of the unfolding vista in answer to the unspoken questions of those who might feel that our membership dues may be at an unnecessarily high level.

New Research Laboratory

It is of particular importance to take special note of the fact that this unfolding vista of the future includes the operation of the recently completed laboratory building which has been constructed by the Association of American Railroads on the campus of the Illinois Institute of Technology. This very fine and modern 50 ft. by 218 ft. two story structure represents an investment of $600,000 by the American railroads. It is designed to house highly specialized electrical, mechanical and container testing laboratories and the offices of the research staffs of the Engineering and Mechanical Divisions of the AAR. This laboratory building may be well described as a milestone in our forward progress. The fact that it has been supplied is a clear recognition of the growing importance of scientific research. We will close this afternoon's session promptly at four o'clock to permit all those interested to inspect this fine facility. The New York Central is providing a special train for the trip to the campus where members of the research staff will receive you and answer your questions. I sincerely hope you will embrace this opportunity and learn first-hand of the broadening field of research contemplated by your industry. And if you do this, you will be better prepared to reply to those critics who admit the railroads have troubles but allege that they do nothing to correct them—that they have problems, but do nothing to solve them.

My reference to troubles is sufficient to remind me that we have found real troubles showing their unpleasant faces in this vista of our future. As members of the engineering profession you have dealt often with the things that caused your troubles. You successfully met the troubles caused in timber by the insignificant but highly destructive termite. You noted the loss of metal due to corrosion and you have done much to protect your metals. In many other instances, you recognized the trouble besetting your engineering structures and you did that which was necessary to meet or to overcome the trouble. But it is the duty of the engineer to shield and protect all structures placed in his care. The finest example of a structural foundation to be found on this globe is the American way of life. But the termites of centralized power and socialism are eating at that foundation and gradually weakening it. And on that line, that wonderful foundation stands the American railroad structure. But you find the corrosive effects of excessive taxation, obsolete and unnecessarily restrictive regulation, and subsidized and uncontrolled competition making their disastrous inroads on the cross-section of that

What of the Members in Remote Locations?

Every association of national scope is confronted with the problems posed by the uneven distribution of population across the continent. Because of this condition, our Association finds a large concentration of the railroads it serves located in the eastern portion of the country and over 70 percent of its membership headquartered in 23 northeastern states. Obviously, this state of affairs was recognized when the Association was organized by the adoption of the constitutional provision requiring annual meetings to be held in Chicago. It also influences the selection of the preponderance of committee meeting places. Your Board of Direction has not been unmindful of the interests of our members in the West and a special Board Committee is endeavoring to develop means whereby the Association can be of greater value to all members and particularly to those situated in the more distant portions of the United States and Canada. A by-product of this study has been to impress upon committee chairmen that non-attendance at committee meetings of those so distantly located is not to be presumed as a manifestation of disinterest. It is hoped that all of our western friends recognize this problem as not lending itself to easy solution.

During the year we have continued to hold the high level of junior membership attained during the year preceding. While many transferred to the grade of member, their number has been replaced by new applicants—in fact, we now have nine percent more junior members than we had a year ago. These young men are indebted to the Association for their acceptance into our ranks. But the Association is indebted to them for submitting their membership applications when they did and will be more so indebted as the years pass. These young men are a real and important part of that vista lying before us. They are the young men who will see the visions. Upon many of them will fall the duty and the pleasure, long before our second half century closes, of directing the work of this Association and its committees. Their very presence in our midst should impel us to greater and even more sincere effort, for they will be the morrow's judges of that which we accomplish today. As the mind and character of a young man are in the impressionable stage, we must take great care that our guidance is well directed, that our observations are soundly developed, that our conclusions will withstand the acid tests of time, of science, of economics and of sound sense. And for the encouraging guidance of these young men permit me to add a few words—words based upon an experience that started 35 years ago and still has not ended. For all you give this Association of your time, efforts and ability, you will be richly rewarded. You will receive many times more than you possibly can give, no matter how much that may be. And as your indebtedness grows, so you will grow.

The Membership

You will shortly receive the reports of the secretary and treasurer and I will not undertake to anticipate what Mr. Lacher will tell you about them. But I do wish to highlight two matters which deserve some special mention. In the matter of membership, many had expressed the fear that this Association might suffer some loss in the total during the year because of the abnormal increase enjoyed during the 50th anniversary year. At one time I would have been highly pleased with the assurance that we would retain our newly acquired membership level. We have done this—and better. At the close of our membership year, February 1, we had 3053 members of all classes, this total representing a net gain of 45 for the year. This does not include 31 applications received prior to February 1 and in process of investigation or approval at that time. I know you share my elation because of this continuing betterment in the Association's representation of the profession.

You know what happened in the following four years, when we increased the membership to in excess of 3000, thanks to the effort of your then president, Mr. Mottier, and his chairman of the Membership Development Committee, who is the man sitting here at my right, Mr. Schwinn. I wish I could show you on a slide the picture that I have just given you. It would bring out better than I can tell you in words, how continuous has been the growth of our membership during the last four years; especially the large jump in the membership of some 674 during the year ended February 1, 1949. Anyone looking at that chart might be somewhat fearful as to what was going to happen from then on, keeping in mind that there was such a sharp jump, the fact that we once lost 1000 members in five years' time, and that there are today fewer railroad employees and officers from whom to draw membership than there were in 1929. Frankly, one might be forgiven for harboring some doubts as to our ability to hold to the 3000 mark or to make further progress beyond that level.

On the other hand, if we look at the other side of the picture, we find ample reason for encouragement. As your president has told you, at the close of our membership year, February 1, we had 3053 members of all classes, this total representing a net gain of 45 for the year. Since February 1 we have added 27 new members, and have also received 40 additional applications. So, it is evident that the recession is not yet with us and I think there are good reasons to believe that we will be able to get more members now, when conditions are more favorable for increased membership than they were in 1929.

Today, there is a greater realization of the value of the AREA to the railroads and to railroad men. Another manifestation of the enhanced standing of the Association and of railway engineers is reflected in the growth of appropriations for railroad research. This is evidenced strikingly in the new AAR central research laboratory on the south side, here in Chicago which will serve as headquarters for intensive railroad engineering investigations.

On the other hand, I would warn you against complacency. There are a number of reasons why we should be able to increase our membership and recoup losses in membership, but we will be able to do that only if we make certain that every man, every railroad employee, who can bring something to the Association and who can get something out of it, will know about our Association, and be given a chance to apply for membership.

President Schwinn: You have heard the reports of the secretary and the treasurer. What is your pleasure?

(Upon a motion regularly made and seconded, the reports (which appear on page 913 were adopted.)

President Schwinn: At the opening of this meeting I referred to it as the concurrent annual meeting of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads. As such, we function as a distinct section of the Operations and Maintenance Department of the AAR. Heading that department is a man who is deeply interested in the same things that interest all of us.

Earlier, I voiced certain comments regarding the value of research. I am not violating a confidence when I tell you that this man once wrote me these words: "Research is of paramount importance to me and my understanding of railroad problems." This man takes a pardonable pride in the completion of the AAR laboratory, a project which he has sponsored since the inception of the idea.

structure. And upon that structure you see imposed a large overload represented by a substantial share of federal deficit spending, of immoderate social benefits and of bureaucratic impositions. The unfolding vista of our second half century will not make a pretty picture unless we assert out right as individuals and actively take a part in the protection of our structures. If we would have our Association continue to grow and to improve its position of usefulness in the industry, we must shield that industry from termites, from corrosion and from crushing overload. Such activity may be classified quite properly as scientific maintenance of railways. I ask you to question yourselves—are you guilty of under-maintenance?

My remarks today would be incomplete if they did not include words of tribute to the many charged with the proper functioning of this Association in furthering its objectives. Your committee chairmen and your committee personnel have performed a highly commendable job. They have given you of their best thought and have developed many excellent reports. All these, with their recommendations, will be presented for your consideration during the coming sessions. Your Board of Direction and the several committees of the Board have been at all times truly and painstakingly considerate of the Association's welfare. They have upheld and guarded its every interest. Our genial secretary, Mr. Lacher, and each member of his staff have given the Association membership, both collectively and individually, the highest quality of service. The research staff, under the able direction of Mr. G. M. Magee, has been exceptionally cooperative and has contributed much to the successful development of the year's work. We are deeply indebted to the Arrangements Committee which functioned this year under the capable leadership of Mr. H. T. Bradley. But for the foresight, planning and hard work of that committee, this annual meeting could not take place. If my year as our Association's presiding officer has brought forth any worthwhile accomplishment, it has been the result of the combined efforts, skill, knowledge, cooperation, willingness to work and friendship of all these. I am sincerely appreciative and grateful.

President Schwinn: The next order of business is the report of the secretary and the treasurer. I will ask the secretary to present these two reports. Mr. Lacher.

Secretary's Statement

Secretary Lacher: The reports of the secretary and treasurer appear in the Year Book (Bulletin 487, March 1950). Your president has mentioned a few of the most important features of these reports and I will adhere to the position I have taken in the past that these reports should not be read to you here. However, I sincerely hope that most of you will take the time to look over these reports when you have time.

I would like to take a few minutes to talk to you about our membership, statistically. As you know, we experienced a large increase in membership a year ago, and I would like to talk to you for a moment about the significance of that. To start with, I shall give you a brief history of the membership.

The history of the membership of the Association can be divided into four periods. The first period covers the time from 1899 to 1930, 31 years, in which there was a remarkably steady growth to 2850. In the next five years, the Association lost 950 members and ended up in 1935 with just a few over 1900 members. The third period covers the following 10 years, which brings us to 1945, during which we succeeded in increasing the membership by only about 100, bringing it to just about 2000.

Rely on Railroads in Times of Emergencies

There seems to be public recognition of the fact that in time of emergency our railroad systems must be capable of handling whatever traffic load such a situation would require both as involves the movement of military and domestic freight and in providing essential passenger services for the armed forces and for necessary civilian travel. But how are our railroads to be kept in readiness for these emergencies if their earnings in peace-time years are inadequate to provide for the proper maintenance of the plant and for the acquisition of the most modern in equipment and facilities. Much of the economies in operation in the future will require capital expenditures; consequently, railroad earnings must be such as will induce investment capital to flow freely into the industry to provide funds for such of these necessary purposes as cannot be supplied out of earnings.

Those elements in the transportation field which are generously subsidized by the government will endeavor to preserve this status and improve it if they can. Even those in places of influence who have but little interest in transportation as such defend these subsidies and point to the land grants which were provided railroads in their early days as an excuse for the continuance of subsidies to these other forms of transportation which are establishing much of their service into areas already having an adequate supply. The proponents of subsidies overlook the fact that the land that was given to a small percentage of the railroads in their early construction days was of no value until the railroads were constructed upon it, and transportation made available for the uses of the people who settled the country after the railroads were built. Congress responded to the argument that the return to the government through lower charges on military freight over the years which saw our country participate in two major wars had liquidated many times over the value of these grants of land to the railroads, and it appropriately enacted a law a few years ago which terminated the arrangement.

I have no wish to bore you with repetitious discussion of the unfairness of subsidies and the fact that they conceal the true costs of providing a competitive transportation service. Nevertheless, a review of the expenditures proposed in the federal and the state budgets would indicate the degree to which these other agencies of transportation propose to use the taxpayers' money to offset losses which without subsidies would be incurred in their activities. As an illustration of the thinking of people in some quarters, I need only to cite one example of how differently problems in the transportation industry are assessed and a remedy proposed. On the one hand, we have a railroad which is unfortunate enough to have a serious train accident. Immediately regulatory authorities set about to determine what element of safety in operation is lacking, and regardless of the fact that a railroad may have a previous enviable record for safety, as almost all of them have, ambitious public authorities will likely prescribe further costly installations to be financed by the railroad. On the other hand, an airliner is in collision with another plane approaching an airport where traffic volume has grown to the point of congestion. In this latter case, public authorities plan to provide an additional airport which the taxpayers will finance. The landing fee charged operators of airplanes for use of publicly financed airports is scarcely more than what you pay for parking your car.

Demands an Aroused Public Opinion

It is my opinion that these attitudes in dealing with transportation matters as between the different agencies will not change unless there is an aroused public opinion which will demand that the time-tested principle that any business undertaking in a competitive field—whether it be in transportation or otherwise—should be self-support-

It is my pleasure and privilege to present a man who needs no introduction—Mr. J. H. Aydelott, vice president of the AAR—who will address us on The Public Should Be Informed.

The Public Should Be Informed

By James H. Aydelott

Vice President, Operations and Maintenance Department, AAR, Washington, D. C.

On behalf of the AAR, I welcome you to this meeting of the Construction and Maintenance Section of our Engineering Division. I hope you will all take the opportunity to go out to our new research laboratory on the campus of the Illinois Institute of Technology. There you will see our new research facilities and meet our research forces—all employed for the purpose of building these railroads of ours into a constantly stronger position.

It is gratifying to see such a large attendance here today. It is something of an achievement to be able to hold these meetings at this time and to discuss the real problems of the railroad industry when other people are talking about developing tools of destruction. I am sure the AREA has always been found to be on the side of developing constructive machines, and of fostering ideas and practices that result in economy of operation of our railroads.

I consider it a privilege not only to be a member of this great organization, but to be permitted to appear on the program of this, its 49th Annual Meeting.

Last year the Association celebrated its 50th anniversary and came forward with a most appropriate slogan, "A past of achievement, a future of opportunity." The significance of the word "opportunity" must not be lost. A new industry will afford many opportunities, but in the railroad industry in its present status in the field of transportation there is a great probability that unless there is constructive thinking toward the development of a national transportation policy fair to all agencies, opportunities for further achievement will be considerably lessened. To secure from the Congress and from the legislative halls of the various states what is properly due our industry on its past record of support to the economy and to the security of our nation will require a concerted effort not only by those who work for or look to the industry for support but also of a large segment of the public in general which, more than it realizes, is vitally interested in the outcome of this effort. There are many confusing issues of the day which make it extremely difficult to focus public opinion upon the ailments of the transportation industry. Most of our people are inclined to take rail transportation service as a matter of course, and there is lack of appreciation of the basic problems which beset our railroads in a nation striving for peace in the aftermath of a war economy and in an atmosphere highly charged with threats of a new conflict.

In my previous appearances before your group, I have stressed the inherent capabilities of the railway engineer to render effective service in the field of public relations, and I repeat that in my opinion something more than the activities of the public relations departments of the railroad industry will be necessary if the people at large are to be educated as they must be on this matter of what is a proper and fair treatment of the railroads in the existing over-all transportation picture.

"It is hereby declared to be the national transportation policy of the Congress to provide for fair and impartial regulation of all modes of transportation subject to the provision of this Act so administered as to recognize and preserve the inherent advantages of each." And quoting further, "all to the end of developing, coordinating and preserving a national transportation system by water, highway and rail, as well as other means, adequate to meet the needs of the commerce of the United States, of the Postal Service and of the National Defense."

The following is quoted from a recent report made by the Secretary of Commerce to the President on the transportation situation: "It should be made clear, however, that federal transportation policy must give major attention to sound and healthy railroads as a part of the transportation system."

It is to be hoped that the investigations now under way will point out clearly the inequalities that now exist and will bring this entire transportation matter to a determination of what should properly be done in keeping with the intent of Congress as expressed in the statute which I previously quoted.

This nation cannot live without its railroads in time of peace, and in time of war they are indispensable, yet, our rail carriers today find themselves at a serious disadvantage in the existing competitive transportation situation in which they see much of their former traffic diverted to other types of carriers which have subsidy advantages.

Of Vital Interest to the Employees

None should be more vitally interested in the success of the railroad industry than we who are employed in it. Unsatisfactory earnings mean loss of jobs and abandonment of programs of the type in which you men are particularly interested. It will be agreed that the railroads have a problem in much of the area which they serve, since they have the disadvantage of any absentee owner of property in being expected to pay taxes and to keep up their property while having little voice in public affairs except as can be had by their locally employed people. It is because of their particular situation that I so frequently dwell upon the importance of local contacts being made additionally by officers of the railroad, particularly those who spend a large amount of their time in the field. It should be our purpose to enlist the support of influential citizens so that their voice may be added to ours in seeking to obtain fair treatment for the railroads. The survival of our railroads as privately owned and operated properties may we'l depend upon how well we are able to state our case to the people. I see it as our obligation, therefore, as railway officers in the operating and the engineering departments to perform these public relation duties wherever we can in the hope that we may be able to enlist support where it is now lacking. Fair treatment of the railroads by our government will insure continued opportunity to individuals and to groups such as this to serve our great industry with honor and distinction. Such has been the good fortune of our generation, and we must preserve to succeeding ones the same opportunities as were afforded us.

President Schwinn: Gentlemen of the Association, Mr. Aydelott holds the same relationship to the Class 1 railroads as the chief operating officer on the individual railroad. As such, he is in close contact with all phases of railway operations and is in a position to speak with authority on the importance of keeping the public properly informed regarding the American rail transportation systems and what must be done to retain them as an official segment of our national economy. Thank you, Mr. Aydelott, for a very interesting and timely address.

ing, and if this sort of policy can be secured the users of transportation and not the taxpayer will henceforth pay the carriage charges. Our representatives in the National Congress and in other law-making bodies are sensitive to the views of their constituents on any matter affecting public policy. Various pressure groups are constantly jockeying to be in the most favorable position when the taxpayers' money is dished out, as they know it will be under the fiscal policies of the government too long existing. The railroads are seeking to have proposals for the expenditure of huge amounts of the taxpayers' money for the extension of inland waterways, for additional aids to aviation and for expenditures for highway development examined to determine if they meet the test of whether the expenditure is justified in the public interest. This is the measure which is applied in the case of proposals for railway extensions and adequacy or inadequacy of existing transportation facilities is an important factor in the decision reached. The railroads further are seeking to have removed war-time taxes on transportation since the war has long since been over and since in the case of taxes on passenger fares they were established primarily to discourage rail travel during the war years. The continuance of this tax has had a depressing effect on passenger travel by rail since it influences a greater use of private automobiles.

The railroads feel they are entitled to greater remuneration from the Post Office Department for the carriage of the mails. Not only have the costs to the railroads for the handling of U. S. mail been greatly increased through increased costs of labor and supplies since existing mail pay basis was established, but the volume of parcel post has greatly increased and it is this particular class of mail which is the most costly for the railroads to handle. In all fairness to the railroads, mail pay increases should long since have been forthcoming.

While there is much public thinking along the lines that regulation of the railroads by the federal government should be relaxed since they no longer monopolize the transportation field, certain groups are attempting to have additional regulations established that would take the government into the field of management by giving it authority to prescribe rules and standards to govern the everyday operating activities of the carriers. Such legislation must be defeated.

Many Economies Realized

With all the ailments which beset the railroad industry their effect would have been much more serious today had it not been for the economies which they have been able to obtain in their operation and maintenance. These have been brought about unbrokenly through the years, and your group has had much to do with them. In going back to no farther than 1941, statistics show that if the use of labor and materials had been on the same basis in 1949 as it was in 1941 the cost of operating the railroads in 1949 would have been approximately nine hundred million dollars more than it actually was. Between the years 1921 and 1949 seventeen billion dollars was spent by the railroads for additions and betterments. Much of this money was spent under the direction of the engineering departments of the railroads and from the results secured it was well spent. There is reason to believe, therefore, that if traffic volume improves and our research activities are adequate, further large savings can yet be made such as will bring the railroad plant and equipment and the operations to a still higher state of efficiency.

A full record of past accomplishments of the railroad industry in the interest of economy and efficiency is being supplied to committees in Congress which have launched investigations in a belated effort to determine how best to carry out the intent of Congress as stated in the Interstate Commerce Act as amended in 1940 and from which I quote:

Until a few weeks ago we were looking forward to the pleasure of presenting this award to Mr. Hastings in person, but that is not to be. As you all know, he is still seriously ill. I am happy to tell you, however, that he is steadily improving and we hope that next year he will again be with us.

Mr. President, I present Edgar Morton Hastings for Honorary Membership in absentia. The certificate will be accepted for Mr. Hastings by his sons, Edgar M., Jr., and David C. Hastings.

President Schwinn: Edgar and David Hastings, I have here the Certificate of your father's election as an Honorary Member in the American Railway Engineering Association. As I believe all those present would like to know what is on this, I will take the liberty of reading it.

> **Honorary Membership has been conferred on Edgar Morton Hastings by the American Railway Engineering Association, this 16th day of March 1950, in recognition of his able and stimulating leadership in this Association and his outstanding service to the railway industry, the engineering profession and his country.**

I ask you to take this certificate to your father, and when you give it to him please tell our good friend that the best wishes of all of us for an early recovery of his health go with it.

(President Schwinn presented the certificate to Mr. Hastings' sons.)

President Schwinn: I have already referred to the milestone in the progress of railway engineering in the fruition of plans for the establishment of a research laboratory devoted to this field. As you are well aware, such a laboratory has become a reality on the grounds of the Illinois Institute of Technology, and is now the headquarters of the research staff of the Engineering Division.

Arrangements have been made to hold "open house" for us at the laboratory this afternoon. Accordingly, we will conclude our session this afternoon at 4 p. m. so that we may go to the La Salle Street station to take a special train on the New York Central, leaving at 4:45. It will return to La Salle Street about 6:30.

(Past-President C. H. Mottier assumed the chair.)

Past-President Mottier: We have a lengthy program before us, and in order to conserve time it is important that we be prompt in our attendance and that we confine our remarks to the subjects under discussion. The privileges of the floor are extended to members and to interested visitors. We hope that you will feel perfectly free in discussing the committee reports as they are presented. This invitation is particularly extended to the younger members of the Association.

The Chair requests that each speaker, on arising, give clearly and distinctly his name and the company with which he is connected, in order to permit the reporter to get them correctly. Attention is directed to the microphones installed in the aisles leading to the platform. You are urged to use them so that what you have to say may be heard by all, particularly if you have detailed comments to offer.

May I suggest, if you have not already done so, that as quickly as possible, you purchase your tickets for the Association Luncheon, which will be held at twelve noon on Wednesday in the Grand Ballroom. Tickets may be purchased at the desk in the foyer.

Presentation of Honorary Membership to Edgar Morton Hastings

President Schwinn: We have one class of membership which is limited to a very small group of men—men who have attained acknowledged eminence in railroad engineering. The immediately preceding Board of Direction had the very real pleasure of electing Past-President H. R. Clarke to be one of this distinguished group. Your present Board of Direction has elected another man from your midst to the class of Honorary Members. This election was announced in the June issue of the AREA News.

It is with a sincere feeling of regret that I must announce that the serious illness of that man, and our good friend, Past-President Edgar Morton Hastings, has prevented him from attending this meeting. I know his thoughts are with us, just as our thoughts are with him, but we miss his presence here today. He will be represented in the acceptance of the Certificate of Honorary Membership by his two sons, Edgar M. Hastings, Jr., and David C. Hastings, both members of this Association. As Mr. Clarke immediately preceded Mr. Hastings in the attainment of this high honor, I have asked him to tell you some of the things which activated your Board of Direction in its selection of Mr. Hastings.

Mr. Clarke, will you kindly take the platform. I would also like to have Mr. Hastings' two sons come to the platform.

Past-President Clarke: Mr. President, fellow members of the American Railway Engineering Association, ladies and gentlemen: To all right-thinking men, an honor or recognition which has not been earned and which is not deserved is an empty gesture. One which has been earned and is, therefore, well merited, is treasured by the recipient far beyond any intrinsic worth it may have.

Edgar Morton Hastings may accept with pride, and is justly entitled to value highly, the honor which the American Railway Engineering Association has done him. Mr. Hastings was born in 1882, studied engineering at Boston Polytechnic Institute and Virginia Military Institute, and is an honor alumnus of the latter. He entered railroad service with the Baltimore & Ohio in 1899, and in 1902 went with the Richmond, Fredericksburg & Potomac, which he served as rodman, instrumentman, resident engineer, principal assistant engineer, and, in 1922, he was appointed chief engineer—a position he has filled with credit to himself and profit to his railroad for 28 years.

He has been a member of the AREA for many years, and has served the Association long and well as a member and as chairman of several committees. He was a director from 1931 to 1934, was elected vice president in 1937, and served as president in the years 1939 and 1940. Thereafter he served as a member of the Board of Direction as past president until March 1948—a total period of service of 17 years.

Last year he addressed the Association on its 50th Anniversary in a stirring and challenging way on A Future of Opportunity.

Not satisfied to serve in one association only, he has been active in the American Society of Civil Engineers, and was president of that society in 1947.

In 1948 he was a member of a mission to China in connection with the government's Chinese Aid Program, under the Economic Cooperation Administration. Specifically, he inspected and reported on three of the principal railroads in China.

This Association has called upon Edgar Hastings many times, and he has always responded. He has often been tried and has never been found wanting. He has been honored by the Association many times and in many ways. Now, in recognition of the work he has done so well, and the service he has rendered to the Association, the engineering profession, the railroad industry, and our country, the Association has awarded him the highest honor it can bestow, that of Honorary Membership.

The Rosy Road to Ruin

By W. G. Vollmer

President, Texas & Pacific Railway, Dallas, Tex.

Presented at the Annual Luncheon on March 15, 1950

The members of your Association deserve the congratulations of all engaged in railroading for the sound contributions you have made over the years to the development and progress of our industry.

More than any other group within the industry, your thinking and your calculations are based upon the logical law of mathematics—a law which states that two plus two equals four, not five, six or seven.

Strange as it may seem, there are many people in our country, both in and out of government, who do not believe in, and have cast aside, this law of mathematics. Their plans and programs are based upon the false assumption that two plus two equals more than four; that the law of mathematics does not apply to the business of government.

This and other methods of false reasoning are taking us little by little down the socialistic road to ruin.

This Rosy Road to Socialism

This rosy road to socialism is paved with wrong assumptions and tempting promises.

The promises run the scale of human emotions, while the lyrics are couched in words which inspire the false belief that the federal government has the wisdom and the power to increase the supplies of goods and services and expand their distribution, by the use of an increasing supply of visible and hidden taxes taken from the people.

Throughout the nation there are people in every walk of life whose actions suggest that they do not question the validity of these distorted assumptions and fanciful promises.

If we are willing to look the facts of life squarely and honestly in the face, the mathematics of commonsense will prove that the federal government cannot fulfill its generous promises with safety to our economy.

The federal government cannot work economic miracles. But it has succeeded in producing some fanciful economic mirages. Many people have come to believe that our government has the wisdom to produce five, six or seven out of two plus two.

Our government is no more able to work economic miracles than is an individual. Nor is it able to transform mirages into realities. These are simple truths all of us must recognize if we are to stay out of trouble.

We must place our faith and our hope in the great principle that our Creator endowed all mankind with the rights of freedom as children of God, with a free will. We must live and work by that principle if we are to remain a free people.

Our founding-fathers had the wisdom and the foresight to embody that principle of freedom in the Constitution. It is the very keystone of that instrument. In a quest for a richer and fuller life, if we turn away from this God-given concept of freedom and human dignity we shall find ourselves embracing the evil philosophy that the rights of man come from the "state." This vicious philosophy of Karl Marx would have us believe that an all-powerful government can perform economic miracles and transform mirages into actualities.

Instead of working miracles for the people, the socialistic philosophy never has produced anything but scarcity, misery and enslavement.

Report of the Tellers

Presented Wednesday Noon March 15, 1950

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the nominating committee, find that the count of the ballots is as follows:

For President

G. L. Sitton 1625

For Vice-President

T. A. Blair 1615

For Directors (Four to be elected)

R. P. Hart 1242
Clark Hungerford 877
W. J. Hedley 815
G. M. O'Rourke 803
A. N. Laird 796
C. B. Porter 732
E. J. Brown 686
R. W. Seniff 557

For Nominating Committee (Five to be elected)

L. L. Adams 1198
Barton Wheelwright 999
E. E. Oviatt 974
M. H. Dick 857
J. E. Fanning 803
Ray McBrian 763
H. Austill 733
W. E. Cornell 609
W. E. Heimerdinger 574
J. E. Bernhardt 515

Respectfully submitted,

THE COMMITTEE OF TELLERS,
R. C. BARDWELL, *Chairman.*

R. C. BARDWELL, *Chairman,*
A. R. WILSON
T. A. TENNYSON
A. E. BOTTS
R. M. STIMMEL
S. H. POORE
R. A. BARDWELL
J. G. GILLEY
A. G. DORLAND
L. C. HARMAN
H. L. MCMULLIN
A. B. PIERCE
M. J. J. HARRISON
F. D. DANFORD
B. T. ANDERSON
C. A. WHIPPLE
G. P. PALMER
A. A. MILLER
E. F. SALISBURY
O. E. MACE
G. R. WESTCOTT
M. J. HUBBARD
W. G. HARDING
G. L. BROWN
S. G. URBAN
R. S. GLYNN
J. F. KERR
G. V. COFFEY
D. E. SPEEG
J. L. LOIDA
W. C. PINSCHMIDT

and services which the government feels the people are incapable of providing for themselves.

The government has assumed or is planning to assume the responsibility of providing, with the people's money of course more and better private houses, a vast and far-reaching expansion of hydro-electric power through the development of projects similar to the Tennessee Valley Authority, high prices to the farmers and lower food prices to the consumers, full employment, greater unemployment insurance and health benefits, an expansion of federal grants-in-aid to states, greater aid to schools for educational purposes, greater public health services, an extension of the public housing program, more hospitals, more doctors, more nurses and more and better pensions.

Now all of these things are laudable.

But the federal government cannot provide them without consuming more and more of the people's income. And the more it consumes, the less able are we to provide these things for ourselves and, thus, the more dependent we become upon the government for assistance. It is a vicious cycle which leads to "state supremacy."

The people occupying positions of authority in government are not supermen. They possess no mysterious powers. Their judgments are not infallible. Their wisdom is not perfect. Their vices and their virtues are no better or no worse than yours and mine.

These simple observations are not intended as a criticism of any individual in government. There are many good men in public service. But there are some who get their heads in the sky, who lose their sense of proportion and who insist that two plus two equals five.

This mathematical myth is like the political myth that a government can spend more than it takes in year after year and still remain solvent. The latter inevitably leads to moral and economic bankruptcy.

You Must Speak Up

Since the soundness of the thinking of men in your profession is generally recognized, it is important that you speak up, whenever and wherever you have an opportunity, in behalf of a national economy based upon such sound rules of reckoning as the laws of mathematics, of supply and demand and of cause and effect.

You can point out that unless individuals and industries of the nation are permitted to keep a fair and reasonable proportion of the fruits of their labors, the money essential to the tools of industry will dry up eventually.

You can point out that today's savings and investments are the germs of tomorrow's productivity.

You can point out that the tools of production represent about 90 percent of our productive energy and that human energy represents only 10 percent.

You can point out that a decrease today in the supply of energy-producing tools means a corresponding decrease tomorrow in the supply of goods and services.

You can point to the fact that the productive capacity of our competitive enterprise system, based upon individual freedom and human rights, has never been remotely approached anywhere else.

You can point to the historical fact that any form of government which undertakes to do for its people those things which they can and should do for themselves will end up in disaster.

You can point to the fact that when any of us, acting individually or as groups or as communities, seek special benefits and privileges of the federal government, we are definitely supporting the principles of socialism.

Before We Travel Too Far

Before we travel too far down the socialistic road to ruin, we should take time to evaluate every benevolent promise of government.

Let us not be deceived into believing that our government can be everything to everybody without cost to anybody.

Let us not be deceived into believing that our government can relieve us of the economic responsibilities of making our own living.

Let us not be deceived into believing that we can accept federal aid, service and assistance and at the same time retain our individual freedom.

Let us not trade our great heritage of freedom and human rights for government hand-outs and for tempting promises of benefits and blessings which never can be fulfilled.

Let us measure these government promises of expanded social benefits and increased economic blessings against the simple mathematical rule that two plus two still equals four.

The government has no money or goods of its own to distribute among its people.

Inasmuch as that is true, then every dollar the federal government spends is taken out of the productive effort of the people. The people's income is now being skimmed off at the rate of thirty cents out of each dollar.

The bulk of the taxes to pay for the fantastic program of socialism comes from the middle income group of people, because the lower income group does not have enough money to pay the bulk and there are less and less in number of rich people left. Just recently some of our federal legislators decided to try to do something nice for these middle income people. They decided that a nice thing to do would be to build about two billion dollars worth of government subsidized houses for them to live in, preferably of solid enough construction to keep out the wolf if not the tax collector. Now that is a thoughtful gesture. But I wonder if it has occurred to these federal legislators that if the middle income group did not have to pay so much taxes to subsidize other things they would not need any subsidies for their own houses. And when everybody is subsidizing everybody else, I would then ask who is going to pay for everybody's subsidies?

It is obvious that whatever the government gives to the people, it must first take from them, or else place a mortgage upon their future earnings. Our government now is using a combination of these methods.

It is obvious that the more the government takes from us in hidden and visible taxes the less we will have to spend and to save.

It is obvious that the federal government cannot pursue programs of giving and taking without exercising control and power over the income and the lives of the people.

It is obvious that when the government exercises control and power over the people it robs them, little by little, of their freedom.

How Far Are We Going?

Therefore, it is important that we ask ourselves, as individuals and as communities, how far are we going to go in our demands upon the government for financial aid, for services, for special benefits and privileges of many kinds.

The answer to that question will determine how much of our freedom we are willing to give up for the government's imaginary social benefits and visionary economic blessings.

The issue of "the supremacy of the state over man versus the supremacy of man over the state" now confronts the American people.

If you doubt it, let me remind you of some of the things going on in government in Washington, all of which are designed to provide a wide variety of so-called benefits

Retirement of Secretary W. S. Lacher and Installation of Officers

President Schwinn: When I entered the employ of the old Chicago & Alton in 1907, I heard of a young assistant engineer named Walter Lacher. He had started his railroad career, also as a rodman, with the same railway two years earlier. I did not have the pleasure of meeting him—probably because I was stationed at Joliet, Ill.,—and he had been guilty of nothing that would have required him to go there. I had no reason to dream that, years later, I would come to know, respect and love him. You have read in the December issue of the AREA News, no doubt with some astonishment, the announcement of his desire to retire at the close of this month.

Because of his long association with Mr. Lacher, and particularly because that association included our Fiftieth Anniversary year when he was our president, I have asked Past-President Mottier to say something that all of us feel—to put in words that which is in our hearts, and to present Mr. Lacher with a tangible indication of this Association's appreciation.

Past-President Mottier: Mr. Lacher, Mrs. Lacher, Members of the Association, Guests and Friends: As Mr. Schwinn has just suggested, and as you now realize, we have come to the place in our program where we recognize our retiring officers, and it is very fitting that at this time we do special honor to Walter Lacher, who joined our Association in 1912, became secretary in 1938, and who now, at his own request, is retiring from active service as our secretary.

Walter, this is just another reminder that we are growing old together. Maybe I should say, growing older together.

I have had close association with Walter Lacher in his work for the past several years, and, incidentally, in the Fiftieth Anniversary year, I had occasion to work with him at perhaps a somewhat accelerated rate. All of you who have had the good fortune to work with Walter will agree with me that he has performed the duties of secretary, and directed the activities of the secretary's office, with credit to himself and to the Association. (Reading from plaque)

The American Railway Engineering Association records its grateful appreciation to Walter Scott Lacher for his faithful and efficient service as Secretary of the Association, 1938–1950.

It is my privilege, distinct honor, and very great pleasure, Mr. Lacher, to present this beautiful plaque to you as evidence of our appreciation for the services you have rendered. You will observe that it is something permanent. We hope you will accept it as enduring evidence of our highest esteem for you and the high esteem in which you are held by the members of the railway engineering fraternity. We hope that it will serve as a reminder to you of many pleasant years of association together, and of our good will, which you so deeply deserve.

With this plaque goes the best wishes of all of your friends in hoping that the years of retirement which lie ahead of you and Mrs. Lacher may be most pleasant. We hope that your years of leisure may give you a better opportunity to associate with your friends, your family, and your eight fine grandchildren.

Mrs. Lacher, will you arise, please? You have seen some visible and audible evidence of our felicitations, our best wishes, and our high regard for both you and Mr. Lacher.

Secretary Lacher: Thank you, Mr. Mottier, for this very fine physical evidence of what is happening here today to Mrs. Lacher and me. As most of you know, the person

You can point out that we cannot demand and accept federal aid and assistance for local projects without granting the same to other individuals, other groups and other communities.

For when we do so demand and accept, we use the tools of the free enterprise system to dig its grave.

In this matter of losing individual freedom and human rights, I fully believe it is later than we think, for the termites of socialism are eating away at the foundation of freedom. Socialism and the ultimate supremacy of state over man are becoming grim realities.

If we are going to turn back, the time to do so is today. Tomorrow may be too late. We must make a choice now or accept the consequences by default.

The high road to life, liberty and the pursuit of happiness, which was conceived by our founding-fathers and embodied in the Constitution, imposes upon each one of us the responsibility and obligation of protecting and preserving our blessings.

A Few Suggestions

In closing I leave with you a few suggestions of what you must resolve to do and which you must urge others to do if our heritage of freedom is to be preserved.

(1) Dedicate yourselves to the principle that our Creator endowed each of us with the rights of freedom as a child of God with a free will.

(2) Reaffirm your faith in the principles of our free institutions and our free enterprise system as embodied in the Constitution.

(3) Have enough faith in our free enterprise system to support it by word and by deed.

(4) Have faith in your ability to provide your own economic security.

(5) Have faith in the principle that individual economic planning is superior to federal economic planning.

(6) Believe so strongly in the principles of our way of life that beguiled promises will not influence you to trade any portion of your freedom for artificial government security and synthetic social benefits.

(7) Have enough interest and faith in our form of government to vote in every local, state and national election on all issues and personalities.

(8) Have adequate faith in your own ability and in our free enterprise system so as to resist the temptation to demand or to accept special government privileges or government handouts.

(9) Realize that government policies and programs which ignore the laws of cause and effect, of supply and demand and of mathematics are doomed to failure.

(10) Recognize that our government cannot spend during prosperous peacetime years more than it takes in and remain solvent.

Other ways of manifesting your faith in the principles of our free American way of life will suggest themselves to you.

The impotant thing confronting each of us is that we must become active crusaders, commencing today, for the preservation of our American heritage.

We must work among friends, neighbors and fellow-workers and we must tell our public servants in local, state and national governments where we stand and what we stand for.

Freedom is a personal responsibility which we can neither shirk nor ignore without suffering evil consequences.

We must take our stand and declare our faith today. If we wait, it may be too late.

In the memory lane into which you will now move, it is the desire, it is the request, of this Association, that you retain this plaque in the place that this Association has prepared for it through its love for you. We hope that each time you stop at this plaque you will reflect on what is imbedded objectively in its words.

In presenting this plaque to you, I use the voice of the Association when I say, "well done, good and noble servant. God bless you and keep you safe."

(The plaque was presented to President Schwinn.)

President Schwinn: Thank you, Mr. Miller. I am sincerely appreciative of this symbol of the Association's esteem. This is a beautiful plaque, and I shall treasure it always. I am humbly grateful for the opportunity that was given me to serve our Association as its president. It has constituted the highlight of my occupational career, and it has been a real and very great pleasure.

The presentation of this plaque also marks the closing moments of my term of office. These moments, likewise, mark the end of service on the Board of Direction of Past-Presidents A. A. Miller and J. B. Akers. The Association is greatly indebted to them for their long and valuable service. Their counsel on the Board has always been sound. It is my privilege to ask you, Mr. Miller and Mr. Akers, to stand and be properly recognized.

(Mr. Miller and Mr. Akers arose and were applauded.)

President Schwinn: The terms of T. A. Blair and W. D. Simpson, who have served you well and faithfully as directors, also expire at this time. I will not ask Mr. Blair to stand as he is not leaving the Board. I am sorry to announce that Mr. Simpson was unavoidably kept from attendance here today.

Mr. G. W. Miller's service on the Board also would have expired today had it not been that the Board reelected him to fill out the term of Mr. Neal Howard, who resigned as a director in anticipation of his new duties as secretary.

I have previously paid tribute to the fine work of the Arrangements committee, under the chairmanship of Mr. H. T. Bradley. But it is appropriate that I now express special appreciation of the many years' service performed on that committee by G. P. Palmer and J. de N. Macomb, or just Major Macomb, to most of you. I also wish to thank the Reception committee for the valuable service which it performed throughout this meeting.

I would be remiss if I did not voice special recognition to that group of women, under the leadership of Mrs. Bradley and Mrs. Lacher, who so kindly gave of their time to act as hostesses in the women's registration room.

My closing action as your president gives me the honor, privilege, and pleasure of introducing to you your new officers.

Our senior vice president for the coming year is H. S. Loeffler, assistant chief engineer of the Great Northern. Mr. Loeffler, will you please come to the platform?

Our newly-elected junior vice president is T. A. Blair, chief engineer of the Santa Fe System. Mr. Blair, will you kindly stand with Mr. Loeffler?

(Mrs. Blair and Mr. Loeffler came to the platform)

President Schwinn: So long as you select vice presidents such as these men, you will have able presiding officers.

You have elected a new president. I talked to him on the telephone last evening and he expressed his keen regret that his doctor's orders forbade his presence here this morning. He requested his long-time comrade-in-arms, Past-President Akers, to represent him in his absence. I will ask Past-President Clarke and Past-President Miller to escort Mr. Akers to the platform.

(Mr. Akers was escorted to the platform)

whom you select as secretary of the American Railway Engineering Association also becomes the secretary of the Engineering Division of the Association of American Railroads. And, after occupying that position as I have for 12 years, I have gained quite an insight into the manner in which the various divisions and sections of the AAR operate, and have noted that much that they do is done in the same way that we do it. But, there is one very definite distinction.

Anybody who participates in the work of the sections and divisions of the AAR, and who works on their committees, does so as the representative of his railroad, so that when he is working for one of these committees, or is acting as a section officer, he is still, so to speak, on the payroll of his own road, and what he is doing is rather definitely in regular line of duty.

That, of course, is not the case with the American Railway Engineering Association. All of you men who participate in its work, as has been evidenced here during the last three days, do so, in effect, on your own time. It is a labor of love, on your part. True, your managements gain considerable from what you do, but that is entirely indirect.

Such a situation necessarily places your secretary in rather a unique position. To put it bluntly, he gets paid for his work, while the rest of you, in the words of members of the Elks Clubs on Tuesday nights, are "just donatin' their own time."

Well, that is something I have tried to keep ever before me. It is something I am telling Mr. Howard, in particular—that when he may become impatient because a committee chairman fails to do something, he should keep in mind that the chairman is donating his time while the secretary is not.

Also, as I think of the last 12 years of service to this Association, it helps me to keep my feet on the ground, especially in view of all the kind things that have been said to me during the past week. After all, 12 years as your secretary is a relatively short time in the 51 years of life of your Association. As the years go by, these 12 years will gradually pale to insignificance, I am sure, in the line of secretaries that your Association has had and will have in the future.

On the other hand, these 12 years are, without question, the most significant, the most important, years in the life that Mrs. Lacher and I have had together. And we are going to cherish them as long as we live.

Installation of Officers

President Schwinn: Have we any other new business?

Past-President A. A. Miller: Mr. President, the year during which you have been president of the American Railway Engineering Association is ending. During that period, under your able leadership, this Association has accomplished many things effectively. Great progress has been made in the right direction, and strictly in line with the intent and purpose of our Association, as expressed in our constitution.

The plaque that is about to be presented to you objectifies the heartbeats of this Association, its thoughts and its feelings. And the meaning of the words that are inscribed on this plaque reflect with deep emotion the high regard, the esteem, and the affection in which you are held by this Association; also, our everlasting gratitude for the splendid leadership and the constant, penetrating direction that you gave during this year. I will read what is on this plaque:

> **The American Railway Engineering Association records its grateful appreciation to Frederick S. Schwinn for his able administration of the affairs of the Association during his term as President, 1949–1950.**

handled by our president, Mr. Sitton. I consider this task not only an obligation, but a privilege that carries with it a definite responsibility to serve our Association. I accept that responsibility, and shall attempt to serve the Association in this respect to the very best of my ability until such time as Mr. Sitton recovers his health.

At this time, it is my pleasant duty to present to you our new directors, the election of which was announced yesterday at the Annual Luncheon. If these men are in the audience, will they please come forward?

Mr. R. P. Hart, chief engineer, Missouri Pacific Railroad.

Mr. Clark Hungerford, president, St. Louis–San Francisco Railway.

Mr. W. J. Hedley, assistant chief engineer, Wabash Railroad.

Mr. G. M. O'Rourke, assistant engineer maintenance of way, Illinois Central Railroad.

(Messrs. Hart, Hedley and O'Rourke came to the platform.)

Vice-President Loeffler: These are our newly-elected directors, and they are ready to start their duties on the Board of Direction.

I still have another and rather unusual duty to perform at this time. Will Past-President A. R. Wilson please escort Neal Howard to the platform?

(Mr. Howard was escorted to the platform.)

Vice-President Loeffler: Mr. Howard, as I am sure all of you know, is the unanimous choice of the Board of Direction as the successor to Mr. Lacher, not only as secretary of the AREA, but also, with the confirmation of Mr. Aydelott, as secretary of the Engineering Division of the AAR.

He needs no introduction to this audience. His long service in editorial work with publications that foster the interests of the railway industry, particularly in engineering and maintenance, and his wide acquaintance among railway engineers, eminently qualify him to take over his new duties and responsibilities. He is an engineer by training, having been graduated from Rensselaer Polytechnic Institute, and before entering the employ of the Simmons Boardman Publishing Corporation in 1924, he served an apprenticeship in railway engineering on the Illinois Central.

Mr. Howard, you have already done so much work for the Association in so many different ways that the job of breaking you in will be insignificant as compared to what it would have been with almost any other new secretary.

Therefore, we have no reason whatever to question the conduct of the secretary's office during the coming year. On the contrary, we have the most implicit confidence that the work will be handled to the high standard set by your predecessor, Mr. Lacher.

It gives me the greatest pleasure, therefore, to install you as our secretary, effective April 1, 1950. Congratulations, Mr. Howard.

Mr. Howard: Mr. Loeffler, I appreciate your kind remarks. I am fully cognizant of the honor that has been bestowed upon me; also of the heavy responsibilities. I am particularly proud to follow a man like Walter Lacher. On the other hand, I could be overwhelmed by the thought of attempting to serve the Association as adequately as he has.

However, as Mr. Loeffler has said, there are a few things in my background that should give me an element of confidence that I cannot fail utterly. It should be a matter of some little assurance to you, that for more than 25 years—and I say it most sincerely—my entire interests have been the American railroads, you engineering and maintenance officers, and your many and varied problems.

My background has been very similar to that of your previous secretary. In a sense we came up through the same school. I know that will be invaluable to me in your

President Schwinn: You have chosen George L. Sitton to lead the AREA on its upward path. Through Mr. Akers, I congratulate him. It will be my privilege to serve under him. I salute him as the president of the American Railway Engineering Association, and wish him success. I have the honor of handing to you, Mr. Akers, this fine gavel as a gift from the Association, and as a symbol of the authority of his office. Will you please hand this gavel to President Sitton?

Past-President Akers: Since it is impossible for Mr. Sitton to be here because of his health, it is indeed pleasing to me to act in his stead at this moment. We sincerely hope that George will soon be in his usual good health, and able to assume the duties of the presidency.

George and I have worked together closely for a great many years in the maintenance-of-way department on the Southern Railway. He is deeply appreciative of the honor conferred on him in his election to the highest office of our Association. He will carry our banner high.

President Schwinn: Is there any other business?

A. B. Pierce (Southern Railway System): Mr. Akers, I would appreciate your recognizing a call to the platform of your friend, and Mr. Sitton's friend and co-worker, Mr. J. E. Griffith, assistant to chief engineer, maintenance of way and structures, Southern Railway System, located at Knoxville, Tenn.

J. E. Griffith (Southern Railway System): Mr. Akers, everyone here regrets that Mr. Sitton is unable to be present. Will you please express our deep feeling to him and give him the following message:

Mr. Sitton, you have achieved high honor in the field of engineering by having been elected president of the American Railway Engineering Association. Your co-workers on the Southern Railway have always been proud of you. That feeling of pride is stronger in our minds now. We know that the AREA will profit by your leadership. All your friends on the Southern Railway System want to assure you of their continuing cooperation. We know that you will have the same from the members of all the other railroads comprising this organization.

However, we want to give to you, as you start your term of office, that feeling of security made possible by the knowledge that each member of this association will gladly perform any task you assign.

The Southern Railway members of the AREA want to present you with a token which you may keep in your possession long, we hope, after the official AREA gavel has been turned over to the hands of those who will follow you. We think it fitting that such a token be a reminder to you of your many achievements. Therefore, we have had this gavel made especially for you. It is my great pleasure to present it to you, with the best wishes of each of us.

(The gavel was presented to Past-President Akers, to be given to President-Elect Sitton.)

Past-President Akers: Speaking for Mr. Sitton, thank you very sincerely for this expression of kindness and generosity on the part of the men who work closest with George. I know the feeling of gratitude that exists among us on the Southern because of George's elevation to the presidency of the AREA. It will be a great pleasure to see that the gavel reaches Mr. Sitton in good condition. Thank you again.

(Vice-President Loeffler assumed the chair.)

Vice-President Loeffler: Under the provisions of the AREA Constitution, it becomes my obligation as senior vice president to take over the duties that otherwise would be

Presentation and Discussion of Committee Reports

Discussion on Water Service and Sanitation

(For Report, see pp. 125–157.)

(Past-President C. H. Mottier presiding)

Chairman H. E. Silcox (Chesapeake & Ohio): Before proceeding with the presentation of the report of Committee 13—Water Service and Sanitation we wish to express to the Association, our loss and regret in the death of Kenneth Plummer Howe, at Louisville Ky., on May 26, 1949. He was elected to membership in the AREA on March 6, 1946, at which time he also became a valued member of Committee 13. A brief memoir to Mr. Howe appears on page 126.

Your committee this year is reporting on eight subjects, which we hope will be of interest and benefit to the Association, and the several subcommittee chairmen will endeavor to present their assignments in such form that they will be informative to those interested in the fields of this committee. (Chairman Silcox then introduced, in order, the presentation of the committee's various reports.)

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman G. E. Martin (Illinois Central) without making any recommendations.

Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR. H. W. Van Hovenberg (St. Louis Southwestern), subcommittee chairman, presented the report.

Mr. Van Hovenberg: Your committee has little to add to what is contained in its published report, except to say that it is expected that the work of the research project now being carried on in Baltimore, Md., will terminate so far as the laboratory is concerned on or about June 30, and that several of the personnel may be retained to complete the writing of reports.

Assignment 5—Sanitation Practices for Construction and Operation of Camp Outfits. D. C. Teal (Chesapeake & Ohio), subcommittee chairman, presented the report.

Mr. Teal: The responsibility for sanitary control of living and working conditions on the railways is not always clearly recognized. This may sometimes be due to lack of knowledge or to lack of interest on the part of those concerned. In this connection, your committee feels that there is definite need for guidance in the basic principles of sanitation.

It is believed that the provision and maintenance of healthful living conditions for railway employes will repay the costs of such many times over by eliminating excessive labor turnover due to discontent, and by the reduction of time losses because of illness. It is further believed that good sanitation in railway labor camps depends on two things; the first being reasonably adequate facilities, and the second, good housekeeping. The report of your committee is accordingly divided into two sections, one covering the physical requirements and the other maintenance and operation.

The recommendations presented were developed with due consideration of all the federal and state health regulations pertaining to camp sanitation that could be found.

Assignment 6—New Developments in Water Conditioning for Diesel Locomotive Cooling Systems. M. A. Hanson (Gulf, Mobile & Ohio), subcommittee chairman, presented the report.

behalf. I am not unacquainted with association work. One of my delights has been working with your Association, and I look forward with the greatest of pleasure to greater service to you all in the future.

Mr. Loeffler, I pledge to you,, to President Sitton, to all the members of the Board of Direction, and to each member of this Association, my greatest efforts in your behalf.

Vice-President Loeffler: Thank you, Mr. Howard.

This completes our program, but before we adjourn, I want to announce a meeting of the Board of Direction in Room 5 on the third floor, to be held at 2 p. m.

The meeting is now adjourned.

(The meeting was adjourned at 1:25).

of crossings, we have prepared two tables which will, at a glance, permit anyone to obtain the Association's recommended type of crossing to be used at highway–railway grade crossings. These tables are illustrated on pages 200 and 201. Each type of crossing is given a reference number as it is presented in the Manual. Only the types of crossings included in the Manual are included in the tables. If and when additional types of crossings are used, we must make a new table accordingly.

(A motion that the two tables be included in the Manual was seconded, voted upon and carried.)

Assignment 3—Merits of Various Types of Highway–Railway Grade Crossing Protection, was presented by Subcommittee Chairman G. P. Palmer (Baltimore & Ohio, retired).

Mr. Palmer: This report is merely for the purpose of getting into the record this information, which we feel is of most importance to every railroad in the country. This study was made over a period of 20 years at a total of 321 highway grade crossings on the Wabash Railroad. If that were to be multiplied by 20, it would be 6420 crossing-years. However, some of those crossings were eliminated, so the actual study covered approximately 6355 crossing-years, which you can readily see eliminates any factors that might be wrong in case the study was over a short period or involved only a few crossings.

Assignment 4—Description and Recommended Use of Various Highway Crossing Signs and Various Types of Highway Grade Crossing Protection, was presented by W. C. Pinschmidt (Chesapeake & Ohio), subcommittee chairman.

Mr. Pinschmidt: Your committee has studied all of the subject matter covered by the assignment and submits the tabulations of data on pages 202–203 with the recommendation that they be approved for publication in the Manual. There are, however, several changes in the text that we desire to offer at this time.

On page 202 in the tabulation headed, "Recommended Use of High–Railway Grade Crossing Signs," column 2, headed, "Sign Recommended," paragraphs 2, 4, and 6, the second sentence in each paragraph should be revised to read as follows:
"Reflecting medium may be reflector buttons or reflecting material."

Past-President Mottier: Let me ask a question. You are going to leave "or reflecting paint" in?

Mr. Pinschmidt: No sir, that comes out.

The first tabulation at the top of page 203 covers supplementary signs used with the conventional crossbuck signs at crossings where watchman service is not maintained or gates are not operated throughout a 24-hour period daily. In the interest of clarity the committee feels the following additions should be made in the second and third columns: Ahead of "Watchman Off Duty" sign, in column headed, "Sign Recommended," insert the words, "One of the foregoing crossbuck signs, together with," and in the column headed, "AREA Manual Reference Pages," opposite this additional description, insert the reference, "pages 9–53 to 9–62, and 9–67 to 9–72." In column 2 change the last sentence under "Watchman Off Duty" sign to read "Reflecting medium may be reflector buttons or reflecting material."

Past-President Mottier: And cut out, "or reflecting paint?"

Mr. Pinschmidt: Yes sir.

Ahead of "Gates Not Working" sign, insert the words, "One of the foregoing crossbuck signs, together with," and the accompanying reference, "pages 9–53 to 9–62, and 9–67 to 9–72." In column 2, change the last sentence under "Gates Not Working" sign to read. "Reflecting medium may be reflector buttons or reflecting material."

Assignment 7—Railway Waste Disposal. T. A. Tennyson (St. Louis Southwestern), subcommittee chairman, presented the report.

Assignment 8—Inspection and Maintenance of Steel Water Tanks. H. E. Graham (Illinois Central), subcommittee chairman, presented the report.

Assignment 9—Corrosion and Incrustation in Return Systems. H. M. Schudlich (Northern Pacific), subcommittee chairman, presented the report.

Mr. Schudlich: I should like to call to your attention Item 3 at the bottom of page 153. Since the fuel situation has become adverse, return and condensate losses become a more important item than is indicated in the report.

I would also like to call attention to the section on page 154 pertaining to the addition of volatile amines to control the carbon dioxide which naturally passes over the steam. Some work has been done on this and it has been found to have very satisfactory results, and is economically justified in many cases.

Assignment 10—Control of Algae and Plant Growth in Water Storage Reservoirs. H. L. McMullin (Texas & Pacific), subcommittee chairman, presented the report.

Past-President Mottier: I would like to say on behalf of the Association that this is a very fine report and gives evidence of considerable work. Mr. Silcox, thank you and your committee members for bringing in a very excellent report. Your committee is excused.

Discussion on Highways

(For Report, see pp. 199–210.)

(Past-President C. H. Mottier presiding)

Chairman W. J. Hedley (Wabash): It is with sincere regret that we record on page 199 the death of Warren Henry, who was killed in a highway accident August 25, 1949. He was one of the valuable members of this committee.

We had six subjects assigned to us this year and have reports on all six.

(Chairman Hedley then called upon the various subcommittee chairmen to present the reports.)

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman H. G. Morgan (Illinois Central).

Mr. Morgan: In the Manual on page 9–53, in the notes referring to Fig. 1—Painted Highway Crossing Sign, delete the second line, which contains the words "and border," and delete from lines 10 to 13, inclusive, the sentence, "Sign shall be white with black letters, unless reflector lenses are used, when letters shall be white on black background."

This report provides that all crossbuck signs be painted white with black letters, and without borders.

(A motion to adopt the recommendations was seconded, put to a vote and carried.)

Assignment 2—Description and Recommended Use of Various Types of Highway–Railway Grade Crossings. Subcommittee Chairman C. I. Hartsell (Chesapeake & Ohio), presented the report.

Mr. Hartsell: Referring to our Manual, we find a description of each type of crossing as approved by the Association. It is the thought of the committee that another description would be a duplication and of little value in the Manual. However, for the primary purpose of having a ready, easy-to-read reference in the Manual to these various types

Chairman Hedley: I appreciate the comments that have been made about the report I presented last year on the results of our experience on the Wabash Railroad. This report has received a lot of favorable comment from various highway, engineering and safety organizations throughout this country and abroad—from as far away as Sidney and South Wales—and it gives me a feeling that somebody appreciates the long hours I spent trying to get the data together.

As retiring chairman, I have been favored very much by a cooperative and loyal group of men on Committee 9, and I have enjoyed working with them during the past three years. I know Mr. Huffman, new chairman of the committee, will have the same support for his administration.

Past-President Mottier: Mr. Hedley, on behalf of the Association I thank you and your committee for your excellent work, and you particularly for the fine work you have done as chairman. Your committee has also done fine work in revising your Manual material. If I am not mistaken, you have practically completed the revision of this material.

Discussion on Cooperative Relations with Universities

(For Report, see pp. 759–769.)

(Past-President C. H. Mottier presiding)

Chairman S. R. Hursh (Pennsylvania Railroad): We have had quite an uphill battle in our undertaking because the railroad industry has been in very severe competition with other industries—the steel industry, the electrical industry, the chemical industry, and most others—during the war and since, which, have been competing for engineering brains as they are turned out of our universities each year. However, I think we can report progress to the extent that we have increased the salary level of the young men starting on the railroads. That has been a wonderful help. We have had a lot of cooperation from additional railroads on a cooperative scheme—training, both young men before they enter as a full-fledged apprentice, and afterwards. This has materially helped selling the railroad industry to the universities.

(Chairman Hursh then called upon the various subcommittee chairmen to present their reports.)

Assignment 1—Stimulate Greater Appreciation on the Part of Railway Managements of:

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity of providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

Subcommittee Chairman J. B. Akers (Southern Railway System), presented this report.

Mr. Akers: The more the committee has looked into this subject and studied the figures which have been brought out, the more important it has seemed to us.

To stimulate greater appreciation of college graduates on the part of management is our own responsibility. We cannot expect our top managements to give close attention to every one of the details on the railroads. The way we are building up the organizations in our operating departments, and in our traffic departments as well, is by taking young engineers from the colleges and putting them through the proper training. In this we have been materially aided by increasing wage and salary rates. We have these young men now but we must be careful to keep them. We must see that our men are

In the tabulation on page 203 headed, "Recommended Use of Highway—Railway Grade Crossing Signals," there are no changes recommended. However, I should like to point out that what may appear to be duplicate references are really separate items. In column 2, under the heading, "Signal Recommended," the first reference to flashing-light signal covers this type of signal with supplementary, "Stop on Red Signal" sign. The second reference to flashing-light signal covers this type of signal with the supplementary "Stop" sign. The first reference to wig-wag signal covers this type of signal with the supplementary "Stop When Swinging" sign, and the second reference to wig-wag signal covers this type of signal with the supplementary "Stop" sign.

The tabulation headed, "Recommended Use of Floodlighting" is offered without comment.

(A motion to adopt this material for publication in the Manual was seconded, put to a vote and carried.)

Assignment 5—Method of Classifying Highway–Railway Crossings with Respect to Public Safety, was presented by W. H. Huffman (Chicago & North Western), subcommittee chairman, who commented on the report briefly.

Assignment 6—Principles for Determining Allocation of Cost of Public Improvement Projects Affecting Highway–Railway Crossings, was presented by J. A. Droege, Jr. (New York Central System), subcommittee chairman.

Mr. Droege: Due to the controversial nature of the subject, it may be well to run down some of the underlying reasons back of the committee's report. The committee had to select, in the first instance, between a method of payment based on flat percentages or on the net-benefit system. Most of my experience has been with the State of New York, where we have a Benefit law with a ceiling of 15 percent. Practically all of the items entering into the computations, such as wages of watchmen, accidents, taxes, maintenance and renewal, etc., have been highly controversial.

In addition to this, we have run headlong into all manner of operating charges; changes in grade, alinement, curvature, length of line, the elimination of slow orders, etc. To cap this off, we have been confronted with a number of so-called intangible benefits. In one instance, the railroad was charged with benefit in the amount of $200,000 due to increased public good will. This increased public good will was attributed to less annoyance to people being delayed at crossings, less ill will on the part of the relatives of persons injured, and fewer accidents at crossings; also to an improved asthetic appearance after the elimination.

The situation got so bad in New York State that the state legislature had to pass a special act permitting the Public Service Commission to settle these cases by agreement, since we couldn't seem to get together on the computation of net benefits.

In Washington, D. C., Public Roads Administrator Thomas MacDonald has been having troubles of the same kind with the Highway Act of 1944, which was also set up on a benefit basis, with a ceiling of 10 percent. He was confronted with 48 states, and God only knows how many railroads. Finally he issued General Administrative Memorandum No. 325, which sets up a schedule of flat percentages covering the various aspects of grade crossing work.

Influenced largely by the experience of the foregoing parties, the committee decided that the practical way to handle this matter was to set up a schedule of flat percentages and abandon the net-benefit theory.

This has been done in the report of the committee, and I do not think it is necessary to go over these items, except to mention the fact that they parallel very closely the conclusions and the schedules set up by Mr. MacDonald in his General Administrative Memorandum No. 325.

the teaching staff, but to their fellow students. Usually, the opinions expressed as to the reactions of students are not accurate.

You will find in the report that approximately 100 students' names were obtained from some 44 institutions, and that up to the first of the year, 32 definite comments, written, were transmitted to the committee; some in very long letters, which could not be incorporated in the report, but which were very revealing of the interesting time the boys had with the railroads.

The most significant thing disclosed is the fact that 27 of the 32 reactions could be characterized as quite favorable to the railroads, and the other few could be said to be mildly unfavorable. This seemed to many of us to be a contradiction of the opinions frequently circulated, that college students do not react favorably to employment by the railroads.

W. B. Rudd (Union Switch and Signal Company): I think that the work of this committee is one of the most important things facing the railroads today. The important point, as I see it, in attracting young men is not the starting salary, but how fast are they going to progress? I have the feeling that we in the railroad industry have not emphasized as much as we should the opportunities for supervisory positions on the railways brought about by the war.

Professor W. W. Hay (University of Illinois): Being on the university staff, I am, of course, particularly interested in the work of this committee. It has done some excellent work. We at the University appreciate the permission given to us by the Illinois Central to inspect its facilities.

I would also like to ask the committee why it feels it is necessary for the railroad industry to cooperate with universities?

Past-President Mottier: I shall be glad to answer Professor Hay as to the advantage, or necessity, of railroad cooperation, and will do so by taking a chapter out of the history of the Illinois Central in this connection.

At the close of the war, we on the Illinois Central were an organization of, relatively speaking, old men, due to circumstances not entirely peculiar to our railroad. We started in 1946 to revitalize our organization with young men at a time, as you will recall, when the whole set-up with the young people of the country was very much upset. Many boys were going to school. The G.I. Bill of Rights, of course, filled our universities, and every boy when he came out had an opportunity to select one of six, eight or ten jobs. If he didn't like one, he would try another.

Since then the situation has changed completely, and at the present time, on our road, we can get all the men we need from applications. That is perhaps a healthy condition, but there is a danger in our not trying to select the best men and in not keeping our shingle hung out at the universities; danger that we might drift back into the same situation we were in before the war.

In 1946 we hired 18 men for our selected training group, and started these boys as engineering aides, junior and senior, and stepped them up in salary progressively in accordance with a fixed schedule. Up to the present time, 10 of these young men have resigned. We only have 8 left, which is a very poor percentage; 44 percent.

However, from then on we have a different story. In 1947 we hired 11, and of that number we have 10 left, which I think is quite remarkable; 91 percent going on the fourth year. In 1948 we hired 15, and we still have 12 of that number, or 80 percent. In 1949, last year, we hired 18, and we have 17 of them left, which is 94 percent.

Now, if you take the over-all, including the more or less unsettled set-up in 1946, we have retained an average of 76 percent. If you eliminate 1946, we have retained 89 percent, which is, I think, a very excellent record.

given training in other departments—in agency matters, in shop matters, in matters of all kinds—and it is your duty and mine to see that our managements realize the importance of this. On my own railroad we have done this for many years, and I would say that two-thirds to three-fourths of all of our operating offices are taken from our apprentice groups.

I hope you will read this report, and if you can help us by giving us more information, it will be greatly appreciated.

Assignment 2—Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure—by Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities. This report was presented by Dean R. P. Davis (University of West Virginia), subcommittee chairman.

Dean Davis: The main activity of the subcommittee continues to be the promotion of visits by railroad men to schools for the purpose of maintaining closer relations between the railroads and the colleges.

A contract worthy of mention was made by Vice-President H. S. Loeffler, wherein he arranged for the railway engineering students of the University of Minnesota to be given an opportunity to make inspections of the yard and terminal facilities of the Great Northern in the vicinity of St. Paul and Minneapolis. While I call your attention to this particular case, I think there are many railroads which are in a position to extend such invitations to various schools throughout the country.

I want to call your attention also to a rather novel and potentially effective method of interesting the youth of the country in railroad service. I refer to the broadcast on Station KNOX, St. Louis, January 14, 1950, which consisted of a panel discussion under the title "Choosing a Career." The primary objective of this program was to interest high school graduates. However, Committee 24 is interested in such a program as this, for many of the high school students of today are the college graduates of tomorrow.

Armstrong Chinn was active in developing this broadcast, and he furnished the information contained in this paragraph.

In addition to the context listed in the report, we desire to place on the record the continued close relationship between E. M. Hastings and the Virginia Military Institute. Mr. Hastings spoke before a group of students there in April 1949, on the subject of China. At this point I rise to a point of personal privilege. Mr. Hastings has been a member of this committee for a number of years, and a most valued member, and on behalf of the committee, and I know I can speak for the entire committee, this association is honored today in honoring Mr. Hastings. We all wish for him a rapid and complete recovery.

Assignment 3—The Cooperative System of Education, Including Summer Employment in Railway Service, was presented by Dean O. W. Eshbach (Northwestern Technological Institute), subcommittee chairman.

Dean Eshbach: Our report has to do with ascertaining the opinions of college students, principally engineering students, with regard to their summer experience on railroads. Approximately 12 railroads regularly employ college students for vacation or cooperative work. The survey was made in a way to include all the students these railroads have employed, and it was made in such a manner that the students would speak frankly. You can realize that it is very important that the experiences which students have had during vacation period work be accurately transmitted, not only to those on

Assignment 3—Form of Agreement for Railroad Force Account Work on Flood Control Projects. H. F. Brockett (Atchison, Topeka & Santa Fe), subcommittee chairman, presented the report, moving that the form of agreement proposed be adopted for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

(The formal committee presentation was supplemented by the following remarks by Mr. Swatosh.)

Advantages Gained Through Uniformity in the Preparation of Agreements

By W. R. Swatosh
Assistant Engineer, Erie Railroad

I could give a long dissertation on this subject but I have decided against doing so. We are all familiar with a tape and chain; we find universal use for them. They are standard, and a measured foot in New York City is identical with the measured foot in San Francisco or any other location in the United States. When these instruments of measure are used, they are uniform and no misunderstandings occur.

The uniform contract or agreement is designed to achieve the same purpose. Of course, there was a time when such uniformity did not exist. The need for uniform contract forms was recognized by our Association 43 years ago. A special committee was organized for this purpose in 1908, and in 1917 it was given the status of a standing committee.

When the Association organized the committee, it did not intend to make every member of the Association his own lawyer, but rather to implement the idea of uniformity in the preparation of agreements, so that, when written, they were readily understood and easily interpreted. In this respect it is believed to have been eminently successful. For an example, I point out that when, in 1917, C. Frank Allen, an early member on this committee, wrote a book entitled, "Business Law For Engineers," he reprinted therein verbatim, with the permission of the Association, the "Form of Construction Contract," prepared by your committee, and which, since it was first published in the Manual, has been considerably refined and brought to current basis.

The Manual contains, as recommended practice, 32 uniform forms of agreements. These agreements bear on all phases of railroad construction, maintenance and operation. They contain essential stipulations, terms and conditions. These are designed to be impartial, fair and legally sound. In the formulation of their language, uniformity has been stressed so that there would be no misunderstanding between the parties to an agreement as to the considerations involved.

Speaking of an agreement being impartial and fair, I am reminded of an incident which occurred on our railroad many years ago. A construction project had been completed and the final estimate of payment was pending. The contractor had operated under a contract substantially in accord with our recommended form, and he was thoroughly familiar with its terms. Due to adverse conditions which were obtained during the execution of the contract, he completed the project in the red. At a conference with the chief engineer, he explained in detail the reasons (over which he had no control) that had caused him to lose money, and for which he was making a claim. The chief engineer listened patiently and then stated that as the agreement was impartial and fair, he would see to it that justice was given the claim. The contractor exploded, "Hell, chief, I don't want justice; I want mercy." The chief admitted there was justice in this eloquent plea.

You may be interested in the salaries we pay. I will give you averages in even dollars. In 1946 we started out with $254, and of the group taken on in that year still remaining, of which there are 8, their average salary today is $365. In 1947 we paid $261 starting salary. Boys taken on in that year are now getting $327. In 1948—you are familiar with how rates went up—we paid $274 starting, and these boys are now getting $312. In 1949 we had a system of starting at $285 and giving the boys a $10 increase each 6 months for the first 2 years. Boys hired in 1949 are now getting $302.

To me, this record is quite interesting, and shows what you can do if your management takes an interest in building up your engineering personnel.

Professor Hay: I would like to know what the Illinois Central, or any other railroad, has gained by cooperation with the universities?

Chairman Hursh: What the individual railroad gets out of cooperating with the universities is almost commensurate with the interest that the railroad takes in the boys. Last year the railroad on which I am employed got 72 boys—and 72 very good ones. You can be more selective if you go to a college; you can get your pick of the men over other industries. What you can get out of it is what you put into it. The striking thing in the report is that those railroads that reported that they had a cooperative system, or furnished some employment, were able to get all the men—and good men—they needed.

Vice-President Mottier: Mr. Hursh, and members of Committee 24, including myself, we of the Association are very grateful for the fine work that you are doing and I also appreciate the opportunity I have had to contribute something. You are excused and the first session is adjourned.

(The meeting recessed at 12:30 P. M. and reconvened at 2:00 P. M.)

Discussion on Uniform General Contract Forms

(For Report, see pp. 159–177.)

(President F. S. Schwinn presiding)

President Schwinn: I am sure you will be interested to know that the name of this committee has been curtailed. It is now the Committee on Contract Forms.

Chairman L. A. Olson (Chesapeake & Ohio), introduced, in order, the various subcommittee chairmen who made reports.

Assignment 1—Revision of Manual, was presented by W. R. Swatosh (Erie Railroad), subcommittee chairman.

(Each of the recommendations of the committee was voted upon separately and all were adopted.)

Assignment 1 (Supplemental Report)—Form of Agreement for Interlocking, G. W. Patterson (Pennsylvania Railroad), subcommittee chairman.

Mr. Patterson submitted a revised form of agreement, which he recommended for adoption and publication in the Manual, with the following changes:

At the top of page 164, in the title, the word "Plant" should be deleted.

Under section 9, on page 168, in the second line in paragraph (a), the word "form" should be "from."

(A motion to adopt the revised form of agreement was seconded, put to a vote and carried.)

Assignment 2—Form of Agreement for Division of Work, Maintenance and Operation of Flood Protection Projects. The report on this assignment was presented by W. D. Kirkpatrick (Missouri Pacific Railroad), subcommittee chairman.

As you know, Chapter 7 of the Manual has long contained specifications for structural timbers. But these specifications, which were sponsored by Committee 7—Wood Bridges and Trestles, have a use that is fairly well limited to heavy timber structures. Since these specifications pertain primarily to stress grades only, they do not provide for the full range of lumber grades, such as yard lumber, which should be included for general building purposes. As a matter of fact, the Manual has never provided any basic material to use in specifying and purchasing ordinary building lumber. The need for having such material in the Manual has long been recognized.

It will be of interest to you to know that in the process of deciding on the particular form to use for our Lumber Specifications for Railway Buildings, we discussed special specifications as distinguished from commercial grading rules, but never with any serious thought that special specifications would provide a satisfactory solution to our problem. The viewpoint prevailed with us that special specifications are not attractive to the lumber producers and are uneconomical to the purchaser. It became evident during the early stages of our deliberations that we would be doing our railways a disservice by trying to impose on them special specifications for lumber. Recognition was given to the fact that practically all railroads buy their entire lumber requirements according to commercial gradings rules. They have learned by experience that it is advantageous for them to do this.

With such knowledge of this situation as a guide, our committee was unanimous in the feeling that we should direct our efforts toward facilitating the use of commercial grading rules. We feel that very satisfactory progress has been made in this direction.

Most of the credit for what has been accomplished in this undertaking goes to the capable men associated with me on this assignment. In addition, we had the benefit of working closely with Committee 7, and we profited greatly by the good counsel and advice received from Messrs. Lund and Newlin of Committee 7, as well as from others of that committee. Incidentally, recent developments in that committee in connection with lumber specifications cause us to feel that our thinking on this question is very much in line with theirs.

The material that we now present for consideration is a tabulation of commercial grades of all species, with descriptive information as to their recommended uses in railway buildings. This tabulation has been checked for accuracy by the organizations that issue lumber grading rules, so we know they are currently up to date and ready for use in the specification and purchase of lumber.

After publication in the Proceedings, and after comments and criticisms are obtained, your subcommittee proposes to submit these specifications, as amended, a year hence. for adoption and publication in the Manual.

Chairman Dorland: We have made considerable progress on Assignment 8—Modernization of Station Buildings, but have no report to submit at this time. However, Mr. C. E. Lex of the Norfolk and Western is going to give us a talk at this time on the use of moving stairways in station buildings. (The address given by Mr. Lex is on the following page)

Chairman Dorland: Thank you, Mr. Lex. I believe it is a fine thing for our Association to have young men like Mr. Lex take an active part in its activities.

President Schwinn: I want to second what Mr. Dorland has said, and I also want to add my thanks and the thanks of the Association to Mr. Lex for a very interesting talk.

Mr. Dorland, your committee continues to present interesting and worth-while information and also carefully polices its chapter in the Manual. Thank you. You are now excused.

The uniform forms of agreements are engineering instruments and are just as important to a project as a slide rule, transit or level. They are the written instruments provided for you; use them.

In closing, I would like to point out that, should members have suggestions for further refinement of any of the recommended forms, or new ones they desire developed, Committee 20 is at their service.

President Schwinn: Thank you, Mr. Swatosh. That was a very interesting talk. I don't think it should take very much imagination on the part of any of us to realize the value of uniformity in our contracts. That is particularly true in the case of the two assignments on which this committee has reported today; contracts which have to do with flood control work. Your committee continues to prepare new forms of contracts as needed, as well as to revise and bring up to date those already in the Manual, for which your committee has our thanks.

Discussion on Buildings

(For Report, see pp. 215–241.)

(President F. S. Schwinn presiding)

Chairman A. G. Dorland (Elgin, Joliet & Eastern), introduced, in order, the various subcommittee chairmen, who presented the committee's reports.

Assignment 1—Revision of Manual. Subcommittee Chairman J. B. Schaub (Illinois Central) presented the various recommendations of the committee under this assignment, in each case moving their adoption.

(All of the recommendations were voted on separately and were adopted.)

Assignment 3—Shop Facilities for Diesel Locomotives, was presented by K. E. Hornung (Chicago, Milwaukee, St. Paul & Pacific), subcommittee chairman.

Mr. Hornung: I wish to call attention to an error in the caption of the illustrations referring to repair shops for diesel switcher locomotives. The word "switcher" should be deleted as the illustrations are for road engines.

Chairman Dorland: This assignment was worked on previously, and at the convention last year it was stated that the report of this subcommittee was delayed because of the serious illness of the chairman.

The chairman was Charles M. Burgess, who withdrew from the committee last year, and who passed away on February 6 of this year, at the age of 63. Mr. Burgess had been with the Erie Railroad for many years, advancing from chainman to the position of chief draftsman in 1943, from which position he recently retired. He had been a member of the Buildings committee since 1945. He was very regular in attendance at our meetings and most helpful, and it is with the deepest regret that we learned of his passing.

Assignment 5—Lumber Specifications for Railway Buildings. H. M. Church (Chesapeake & Ohio, retired), subcommittee chairman.

In the absence of Mr. Church, Chairman Dorland read the following statement submitted by Mr. Church.

AREA Committee 6—Buildings, started work on this assignment more than three years ago under a subcommittee chairmanned by Mr. W. E. Webb. After doing some of the initial spade work, Mr. Webb found it necessary to relinquish the chairmanship and H. M. Church inherited the privilege of carrying the assignment forward.

The reversible type of moving stairway is best suited for installation in a passenger station since after arriving passengers have been moved to the concourse level, the direction of travel of the stair can be reversed and the departing passengers moved to the track level. This reversing of the direction of travel can be controlled by a key-operated switch located at the top or bottom of the stairs, as desired, and the attendant or usher can reverse the direction in a matter of seconds.

The various manufacturers have inspection and maintenance service that is available for approximately $70 a month, which keeps the moving stairway operating equipment in first-class condition and all motors and controls in adjustment.

Precautions to Prevent Accidents

Up to this point I have attempted to bring out the good points about the installation of moving stairways and a few of the construction details. Now I would like to inject a note of caution that should be noted by those present, since we are all vitally interested in the prevention of accidents to our employees and our patrons.

Among the thousands of people who ride on moving stairways there is the very small percentage who stumble and fall, either while getting on or getting off the stairway, and it is this small percentage that causes the railroads to take safety precautions to keep falls by people at a minimum.

As you all know, a fall by a passenger can result in a claim against the railroad involved, and in this time of increased operating expenses any claim that can be avoided is just that much money saved. For this reason, railroads which have moving stairways in operation, or those which plan to install them in the future, should provide the following safety measures on their moving stairways:

1. Paint the landing plates at both top and bottom of the stairs with diagonal red and white stripes so they will contrast sharply with the color of the moving treads.
2. Paint a one-inch wide white or focal orange stripe on each tread at the nosing to show more clearly where the break occurs.
3. Paint one-inch wide stripes on the moving handrails at three-foot intervals to show more clearly that these handrails are moving.
4. Install on each side of the stairway housing, at both bottom and top, signs reading "Please Hold Handrail," or signs with similar wording. These signs may or may not be illuminated, depending on the lighting arrangement in the stairwell.

The safety measures described are the result of careful study of the circumstances that surrounded many reported falls on moving stairways, and there is no doubt that the adoption of these precautions will keep falls at the minimum, since I have noted from personal study of a series of accident reports that the people who stumbled and fell either misjudged the distance of the moving tread to the landing plate at the top or bottom of the stairs, or put one foot on two treads at the same time as they were starting up the stairs. Both of these conditions were corrected when the landing plates and tread nosings were painted as I have described.

Some people become dizzy while riding on a moving stairway, and for that reason the handrails should be painted and signs installed instructing people to hold onto the rails, since one person falling may possibly knock down others, with resulting injuries to all concerned.

In conclusion, I repeat that moving stairways are expensive to install, and safety precautions must be taken to keep falls on them at the minimum. But the installation of a moving stairway in a modernized passenger station which has long, steep stairs leading to the track level will speed up the transfer of passengers to and from the track level, and will greatly improve public feeling toward the railroad; and it is the public which, in the last analysis, pays to ride the trains.

Moving Stairways at Passenger Stations

By C. E. Lex, Jr.

Assistant Engineer Buildings, Norfolk & Western Railway

During the past ten years the railroads of the United States and Canada have undertaken a full-scale improvement program which has covered all phases of their operations, and which has resulted in the improvement of the locomotive, the lightweight passenger coach, the streamlining of yards and terminals, and the modernization of passenger stations.

My talk will concern itself with the use of moving stairways in connection with the modernization of passenger stations, and I shall attempt to present information that will be of use to all of you, both in the event you now have moving stairways in use on your particular railroad, or plan to install them in the future.

We are all familiar with the old-style passenger station with its elaborate trim, inadequate plumbing and awkward facilities for handling passenger traffic. It is gratifying to note that these are being replaced by modernized passenger stations which are carefully planned for the smooth and comfortable handling of passengers to and from trains.

Many passenger stations of the country are so situated that the ticket office, waiting rooms and concourse are above the tracks and passengers must use long, steep stairs in going to and from the track level. These long, steep stairs have been the source of a great deal of criticism by the traveling public.

This criticism has not gone unnoticed by railroad managements, as is evidenced by the fact that railroads are installing one or more moving stairways in some of these stations as they are modernized. In addition, the installation of a moving stairway will speed up the handling of passengers to and from the track level, and will eliminate the use of the baggage elevator by people having disabilities that prevent them from climbing stairs. All these factors, added together, will improve public relations and will help toward offsetting the high initial cost of approximately $43,000 for a moving stairway.

Data on Moving Stairways Readily Available

There are several well-known manufacturers of moving stairways, and the architect or engineer who includes a moving stairway in his plans for modernizing a passenger station can find all the necessary design details in Sweet's Architectural Catalogue. If any additional data are needed the various manufacturers will supply them free of charge. However, for the information of those present, I shall give a general description and the overall dimensions which will apply to a typical installation.

The average moving stairway is 3 ft. wide between handrails, moves at the rate of 90 ft. a minute, and can carry up to 6000 persons per hour, which is sufficient for the great majority of installations. The 3 ft.width between handrails has been found necessary since most passengers carry their hand baggage and a stairway with less width is not too satisfactory.

A 3-ft. wide moving stairway with a vertical rise of 21 ft. requires a stairwell with an out-to-out width of 7 ft. 6 in. and a length of 67 ft., which cuts down sharply on the side clearance between the stairwell walls and adjacent tracks, and eliminates that portion of the platform for the loading or unloading of baggage unless the track centers are shifted to a minimum of 10 ft. 6 in.

Mr. Knowles is survived by his widow, the former Bessie Baker; a son, Robert H. Knowles, of Minneapolis, Minn.; a grandson, Robert H. Knowles, Jr.; a brother, Myron Knowles of Tampa, Fla.; and a sister, Mrs. Margaret Bougart, also of Tampa.

Past-President E. F. Wendt: Charles Allen Knowles was associated with me for a number of years, both in the work of the Interstate Commerce Commission and afterwards with the Chesapeake & Ohio. He was one of the ablest men that we had in the government in connection with railroads.

(Chairman Mannion then called upon the various subcommittee chairmen to present the committee's reports.)

Assignment 2—Bibliography of Subjects Pertaining to Records and Accounts, V. H. Doyle (Chesapeake & Ohio), subcommittee chairman.

(It was pointed out that the bibliography contains 6 books and some 80 pamphlets dealing with railroad records and accounts.)

Assignment 3—Office and Drafting Practices, W. M. Ludolph (Chicago, Milwaukee, St. Paul & Pacific), subcommittee chairman, presented the report.

Assignment 5—Construction Reports and Property Records; Their Relation to Current Problems. Subcommittee Chairman Louis Wolf (Missouri Pacific Railroad) presented the report and moved its adoption and publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Assignment 6—Current Developments in Connection with Regulatory Bodies and Courts, H. T. Bradley (Missouri Pacific Lines), subcommittee chairman.

Mr. Bradley: There are two items in our report which are of especial interest, and to which I wish to call special attention. In years gone by, the Interstate Commerce Commission developed a method for determining rate-making values which was based on an approximate average of cost of reproduction at current prices, and original cost, both depreciated, plus the appraised value of land and an allowance for working capital. The results obtained by this method were not duly generous, but the method was so flexible it seemed almost invulnerable to serious attack. Following the decision of the U. S. Supreme Court in the Hope Gas Case, the Commission apparently decided that cost of reproduction should no longer be given any weight in the determining value.

With this idea in mind, it hit upon a new formula which was used in Ex Parte 166 and 168. This formula was based on the sum of original cost, the present value of land, and an allowance for working capital, less depreciation and amortization accrued on carrier's books. The Commission was very frank in explaining its method, and no claim was made that any judgment was involved.

On October 26, 1949, the Commission made a valuation of the Ajax Pipe Line Company, and apparently the use of the new formula gave such low results that it went back to the use of its original method involving cost of reproduction. We hope this is an indication of what it will do the next time it is confronted with a railroad rate case, as the difference is about three billion dollars.

The other subject to which I refer relates to whether depreciation should be accrued on a straight-line basis or on a use basis. On a straight-line basis, accruals are made in equal amounts over the life of the property, whereas on the use basis they would vary according to the volume of business handled. In good years the accrual would be greater, and in bad years it would be smaller, which appears to be desirable, both from an earnings and income tax standpoint.

Our report touches on this problem as presented by the Canadian Pacific in a Canadian rate case. You will probably hear more about this subject in future years.

Discussion on Records and Accounts

(For Report, see pp. 413–430.)

(President F. S. Schwinn presiding)

Chairman M. F. Mannion (Bessemer & Lake Erie): The committee wishes to express its deep sorrow in the death of Charles Allen Knowles. His death occurred after the publication of our report, so the committee wishes to read into the record at this time the following memorial to Mr. Knowles:

Charles Allen Knowles, son of George C. and Thankful C. (Miller) Knowles, was born in Buffalo, N. Y., February 23, 1883, and died in the Kecoughtan Hospital of the U. S. Veterans Administration at Hampton, Va., January 31, 1950. He was buried with full military honors in the National Cemetery at Arlington, Va.

Mr. Knowles started his engineering career in 1902 as rodman on the Delaware, Lackawanna and Western, and subsequently held the position of instrumentman, resident engineer, and assistant engineer on the Buffalo and Susquehanna; New York, Pennsylvania and Southwestern; Jackson–McKernan Construction Company, and Norwich, Colchester and Hartford Traction Company, leaving the latter company in 1910 to engage in private practice.

In 1912 he re-entered railroad service on the design of track structures for the New York, New Haven and Hartford, and in 1913 was employed by the United Fruit Company as assistant engineer in charge of railroad location surveys in Central America. In 1914 he returned to the United States and became structural designer for the Central Railroad of New England (now part of the New Haven System).

In February 1914, he entered the service of the Bureau of Valuation, Interstate Commerce Commission, and served successively as instrumentman, computer, recorder, assistant field engineer, and senior civil engineer, resigning in September 1918, to enter the U. S. Army during World War I.

He was commissioned first lieutenant and served with the 3rd Battalion, 55th U. S. Engineers until January 1919, at which time he returned to the Bureau of Valuation as senior civil engineer, where he served until June 1924, when he resigned to enter the service of the Chesapeake and Ohio.

In June 1924, he was appointed assistant valuation engineer of the Chesapeake and Ohio, and served that company for the remainder of his career. In 1925 he was appointed valuation engineer, in 1943 assistant to vice president, and in 1947 assistant to the comptroller. On June 30, 1948, he was retired from active service, and retained as tax consultant, in which capacity he was serving when stricken by his final illness in February 1949.

Mr. Knowles became a member of the American Railway Engineering Association in 1925. He was a member of Committee 11—Records and Accounts, from 1926 until his death, serving as chairman for five years, 1938 to 1942, inclusive. He was also a member of The American Society of Civil Engineers, The American Society of Military Engineers, and of the Accounting Division, Association of American Railroads.

He was a member of the Eastern Grading committee and Accounting subcommittee of the Valuation Advisory committee of the AAR, serving as chairman of the Accounting subcommittee in 1942 and 1943.

Mr. Knowles was a valuable member of Committee 11, and was very active in its work. He will be missed on the committee, not only for his untiring work in progressing its assignments, but also for his wise counsel. He will be long remembered for his devotion to duty, loyalty, and genial personality.

The late lieutenant general of the United States Army, James G. Harboard, has said:

> The roads you travel so briskly lead out of dim antiquity, and you study the past chiefly because of its bearing on the living present and its promise for the future.

Briefly but deeply that expresses exactly what Committee 11—Records and Accounts, is saying to the railroad industry today; records, both historical and running, can provide in great measure the means for fulfilling that promise for the future, if selectively and purposefully prepared, skilfully analyzed and fearlessly used.

Sir Norman Angell is reported to have said that:

> It is not the facts which guide the conduct of men, but their opinions about facts—which may be entirely wrong. We can only make them right by discussion.

There might properly be added to this, "Face the facts and fix it."

The thought here is that mere opinions let loose and running rampant; and the ignoring of facts, or not having them, may lead, and generally do lead, to something entirely wrong. Sir Norman Angell said, "We can only make them right by discussion." If from discussions we could with certainty know the facts, and act upon them, that would be sufficient; but I do not believe we get all the facts that way, otherwise there would not, as of now, be so many things to fix. Adding to the discussion, the elements of deep, and ever deepening deliberations and sure adequate analyses foundationed on facts reflected from good historical and running records, and on the direction that the measuring of us through adequate accounting would help to give, we may have all that is needed to caution us, and to prevent our going beyond sufficiency, which is, and always has been, extravagance; and that no engineer can ever justify if he knows it, and should not be comfortable or complacent about it because others do not know it. Information given under Assignment 4, if objectified, will keep the engineer and those he is responsible to (which includes the public) safely on this side of extravagance.

Obviously, time does not permit of reading the report made under Assignment 4, but I think it would be a very good thing to do—slowly and studiously. Railroad men, particularly executive officers; operating, accounting, engineering and maintenance officers should read, study and analyze it when alone; and ponder it for the sake and benefit of the future. We all have a lot of finding out to do to get the values out of this melting pot; and a lot of constructive work to do to help in the ladeling off of the dross of no value which only retards our progress toward a more certain economic future. Energy, now used in ladeling, can then be used in setting up the machinery and processes for obtaining all the facts; and the providing of adequate measurements for "what we said," "what we did," and in "what degree" the two are alike so far as economic results are concerned; in other words, were satisfactory and economic results obtained when compared to the recommendations made and the authorities granted? This would of course appreciably help to "mould us anew," for "facing the facts" would certainly tend to "fix it" when records and statistics reflect "it," and accounting measures "it."

A few excerpts from the report made under assignment 4 may prompt some intensive thinking about this whole matter, for this atomic, explosive cycle of time calls for our being more certain of the future rather than just being complacent with "what was and is," together with having merely hopes and desires that our economic future will be all right.

Assignment 7—Revisions and Interpretations of ICC Accounting Classifications, H. N. Halper (Erie), subcommittee chairman.

(This report was presented in name only, by Chairman Mannion.)

Chairman Mannion: The committee has no report on Assignment 4 this year. This subject is a very important and timely one. The development of statistics can be of invaluable help to management. Instead of a report on this assignment, we will have an address by one who has made considerable use of statistics in his railroad work, and who is well known to all of you. I now present A. A. Miller, former chief engineer maintenance of way, Missouri Pacific Railroad, and a past president of the Association.

Vital Statistics in Railway Engineering

By A. A. Miller

Retired Chief Engineer Maintenance of Way, Missouri Pacific Railroad

The matter of the use of vital statistics in railway engineering calls for continuing and penetrating considerations, discussions, deliberations, analyses and unfoldments, as more and more facts are brought before us for our measurement, evaluation and the use of them. Therefore, what is said now in a space of time, necessarily limited, hardly touches the purposes, patterns for progressive procedure, values, and substance of all that is embedded in the matter.

Committee 11—Records and Accounts, in its report last year presented to our Association information, under Assignment 4—Use of statistics in railway engineering, which I think should be carefully read by any of our members who are interested in "Revealing Records" for the guiding of us; and "Adequate Accounting" for the measuring of us.

In the Proceedings, Vol. 50, 1949, page 461 to page 471, inclusive, there is found very much of vital importance; and I think it should certainly be read and studied by railroad presidents, chief engineers, operating officers, and accounting officers, as well as all others who have to do with railroad installations, applications, operation and maintenance, respecting or relating to the physical property. Further mention which will be made of Assignment 4 has reference to the Proceedings, Vol. 50, 1949, pages 461 to 471, inclusive.

Such reading and studying will naturally bring to bear upon this whole matter the thinking, reactions and well-thought-out suggestions from many respecting values of such vital importance, for surely our job and our business, in major part, is to do those things, or help do those things which provide proper returns on investments, as well as to comply with laws, and to serve the public adequately. In other words, to protect progress safely and economically, as well as to completely fulfill commitments, and to keep ahead of any progressive enthusiasm of the mass thinking and reactions of our people who, consciously or otherwise, lean upon and are supported by transportation, the most strengthening, influencing and vital part of which is generally conceded to be railroad transportation.

Good historical and running records, *which are statistics,* to *guide* us safely; with adequate accounts and penetrating accounting to *measure* us economically as it is related to the work rather than the word of efficiency, will in the thoughts of many give more positive direction for a greater certainty in the future (which future begins tomorrow) than now obtains.

To that I would add: as a means of providing a rating of efficiency; making more certain the results intended by our purposes and pursuits; and as a means of relatively measuring our recommendations, the authorities granted, our performances and the results.

Some progress along these lines on quite a few railroads has been noted by Committee 11, and in its report last year a few of those railroads are named; there undoubtedly are others. On one of those railroads, other than my own, I am fairly well informed with respect to the use made of statistics, historical records, running records, accounts and accounting for the programming and the doing of work; measuring the present performance; and giving direction for the way toward the future.

In regard to this matter I hope I will be pardoned if I say something about my own railroad.

Springing out of experience which involved using 10 to 15 percent of my time, and the time of many others, searching old records and files to answer questions, prepare statements, make graphs, convince of a recommendation, feel fairly certain of the direction being taken, etc., there was brought into being about 17 years ago on the Missouri Pacific what has now come to be commonly known as the Year Book. It took about two years to prepare the first book because we went back from 20 to 30 years in the files and records to find what was done, why it was done, and to get as nearly as possible a good picture and measurement of use and its effects on maintenance, etc.

The book contains facts with regard to many things—in number about 330. Each year there is added to it the facts of the year before. The information in the book has been a source of what I will call economic inspiration for me, as well as being a very good guide. It brings you up with a caution and care, and prompts a studying and analyzing before "taking off." Coming out of it one seems to hear voices of the men from the past saying, "We may have made mistakes, and probably did; let the record of our experience help you; avoid the pit-falls of opinions, and walk on the firm ground of facts; watch closely and be cautious about the direction you take."

I do not say that the information in this Year Book, or running record, establishes one on the point of perfection and thereby justifies one's saying, "Thus far and no further, for this is all." But I do say that it provides a means of projecting the good of the past, and the benefits of our present experiencing, into our thoughts and analyses, for a better economic balancing of performance for the future; and that it serves as a leaven for our thinking through to the end, in order that the direction to economic certainty for the future may be more clearly defined.

Statistics, when adequately and fearlessly used, will reduce to a great extent the influence and effects of opinions, of the exercise of immature judgment and of opinionated authority, thereby increasing and maintaining efficiency. We can only know what efficiency, in reality, is by a skillful use of statistics to direct the way, and by adequate accounting to measure the in-put and out-put.

I hope that your running record, or Year Book, will be good; and that the accounting for you and the account of you will also be good, and as time goes on, better!—and ever better and better until we have reached the best!

(Past-President A. R. Wilson assumed the chair.)

Past-President A. R. Wilson: Mr. Miller, you are to be commended for this interesting and valuable paper. Please accept our thanks for this constructive information.

Past-President E. F. Wendt: The Committee on Records and Accounts has been in existence now for 50 years, has done a vast amount of work, and is now prepared to do even more work than heretofore.

> The use of statistics in the engineering department of the railways is important and necessary in the administration of the affairs of the department that has in its custody the fixed property and the responsibility for construction and maintenance work.
>
> * * * the interpretation and determination of the significance of statistics require much skill
>
> * * * statistical methods are superimposed on accounting results with data in the process of understanding the circumstances of the past and present performance, with the view of controlling present or current expenses and in forecasting the future money outlays and other activities of the engineering department.
>
> It is also necessary in the administration and operation of the engineering department to maintain historical and comparative statistics of the past years down to date, so as to have the results of the past in compact and convenient book form, appropriately indexed and arranged.

The thoughts embedded in these few quotations from the reports, when considered together, mean that those making use of statistics for the purpose of immediate control, setting up the proper direction for future economic procedure and processing, and setting up guide posts along the way, must be more than partially informed; they must be very nearly completely informed. They must at all times be aware of objectives; know a great deal, and preferably all, about the physical conditions of the property; the density and speed of traffic past, present and visualized for the future; the "value of the dollar" past, present and a hope for the future; the use of physical units as related to density of traffic or tonnage handled past, present; and with good statistics and adequate accounting provide a safe projection into the future.

The thoughts embodied in the report also prompt the quizzing of ourselves a bit Except for complying with legal requirements, different commissions' requests and requirements, etc., how important, how necessary, how selective are the statistics now available to us, and to what kind of use are they put? Are they used as a tool for doing those things which would weather economic storms? If not, the tools may either need sharpening or, if fit, put into good use. The future, seeking economic stability and safety, is looking right at us who are of this day.

I think that good historical and running records and statistics with their facts, and adequate accounting with results clearly defined and sharply outlined, will plainly indicate the importance of and the vital necessity for a more positive use of statistics in railway engineering and maintenance if we are to hit the economic bull's eye oftener and with more certainty.

It has been said that "An engineer is a man who can do with one dollar what most anyone can do with two."

This is a challenge to us engineers at any time, in any generation. To keep safely sure that that challenge is successfully met in our time, right where we stand—for there no longer is space or spread provided behind a frontier moving westward—I think that good records and statistics are quite as important for us now as reconnaissances and surveys were when the frontier was moving westward; and that penetrating accounting methods would be more useful to us now than preparing accurate maps was then.

At the end of the report under Assignment 4 we read:

> Statistics can be used more widely and effectively as a means of promoting economy and controlling costs.

under the chairmanships, respectively, of I. C. Brewer (Chicago, Milwaukee, St. Paul and Pacific) and W. T. Rice (Richmond, Fredericksburg and Potomac).

A final report on one or more of these subjects will be presented to the Association at next year's convention.

This year's report includes about 25 minor revisions, which are being recommended in the main to bring some of the older wording in the Manual into closer agreement with more recent operating practices. However, one section of the report, on page 90, contains three minor errors made by the printers, which should be corrected to avoid misunderstanding. The first is on page 90, in the third line from the top of the page. The word "insert" should have been printed in the sixth line.

In the ninth line from the top of page 90, an asterisk should have been printed immediately following the word "Signals."

And third, the new footnote following that asterisk at the bottom of page 90 should have been printed immediately following, or underneath, the 13th line from the top of the page.

(A motion by Mr. Allen to adopt all of the changes recommended by the committee was seconded, put to a vote and carried.)

Assignment 3—Methods and Formulas for the Solution of Special Problems Relating to Economics of Railway Operation, B. T. Anderson (Union Switch & Signal Company), subcommitte chairman.

Mr. Anderson: Since our first Monon report in 1948, the detailed operating data for the years 1947, 1948 and part of 1949, have been added, as shown in Tables 1, 2 and 3 on pages 92 and 93.

The economies resulting from the motive power, equipment, roadway and signal programs are listed, with the charges made to capital account and operating expenses.

On page 97, under "Signal Program," attention is called to an error in the heading, "CI&L, R&E Cost", of the three interlockings. This heading should be "R&E, Cost", as the amounts shown are the total costs on the railroads involved, and not the CI&L costs.

A further report on the Monon's modernization program will be made as data become available.

Assignment 5—Electrification and Development of Modern Power Units, L. K. Sillcox (New York Air Brake Company), subcommittee chairman.

(In the absence of Mr. Sillcox, the report was presented by H. D. Walker.)

H. D. Walker (Illinois Central): In 1947, we explored the field of comparative steam and diesel-electric operating and maintenance costs, as well as the pertinent operating indicators, with inconclusive results. The statistical comparison which ensued admittedly was susceptible to two criticisms. First, we were unable to obtain data in sufficient quantity for a given design to support any definite conclusion, especially in view of the scattered pattern of the meager data received. This nullified our first objective of determining the effect of age on maintenance costs. Secondly, the diesel data obtained were applicable to relatively new power, while those submitted as the result of experience with steam locomotives were developed from old units or, at the best, from a combination of obsolete and modern designs. Thus, our second objective escaped us.

Another attempt to gain these objectives was made in 1949, and the data developed form the basis of our present report. I direct your attention to the fact that this report is submitted as information, and as a partial basis for evaluating the economics of diesel-electric locomotives. Our earlier effort to obtain data applicable to modern steam locomotives was repeated with the same unsatisfactory results, and it was the consensus of the committee that no benefit would accrue from including such material in our report.

During these 50 years, this committee has lived with the Association of American Accountants. It has worked with that Association. There has been no trouble in accounting, which is a record that commends itself to the entire association.

As Mr. Miller has pointed out, this is the committee that develops the facts respecting costs. A lawyer said to me a few years ago, "Mr. Wendt, a lawyer has no case at all before a court unless he has facts." Now, where are you going to get these facts? From the accounting department? No, you get them through the work of the engineer, who sees the renewals, the repairs and the improvements. Such facts form the fundamental accounting records, on which all other cost records are based.

Past-President Wilson: Mr. Mannion, I wish to thank you and all the members of your committee for the good work you have done during the year, as evidenced by the excellent report, you have just presented. You are now excused.

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 87–124.)

(Past-President A. R. Wilson presiding)

Chairman C. H. Blackman (Louisville & Nashville): The most important subcommittee matter before every committee, now that the Association is 50 years of age, is the revision of its old material in the Manual, in order to keep that material up to date. So, the most important of our subcommittees is No. 1, Revision of Manual. We have this year an excellent chairman of that subcommittee. He has done a lot of hard work and is one of the best subcommittee members I have ever seen.

(Chairman Blackman then introduced, in order, the various subcommittee chairmen, who presented their reports.)

Assignment 1—Revision of Manual, E. G. Allen (Atchison, Topeka & Santa Fe), subcommittee chairman.

Mr. Allen: Before taking up the subcommittee report, I would like to say that E. E. Kimball, who served so long and well as former chairman of Subcommittee 1, last year found it necessary to request that he be relieved from the chairmanship, although he consented to remain on the subcommittee as advisory chairman. In organizing our work on revision of the Manual, Mr. Kimball had planned at first to collaborate with the Mechanical Division of the AAR in a revision of Committee 16's section on Power. He also is working on putting into final shape for inclusion in the Manual, a considerable amount of new material on traffic capacity and trade forms, which he personally prepared and presented before the 1947 and 1948 annual conventions of this Association. He also has found that several other important sections in Committee 16's chapter in the Manual are due for revision, additions, or both, and in view of the amount of time and investigation which such would call for, he has found it desirable to turn over three of those subjects for special handling by smaller groups of the subcommittee. These three subcommittees are designated as Assignment 1–A, Assignment 1–B, and Assignment 1–C, and are being handled under the chairmanship of A. L. Sams (Illinois Central), J. P. Ray (Baltimore and Ohio), and H. D. Walker (Illinois Central), respectively.

Last fall and last January, for the same reasons, two other sections, important sections, were handed over, as Assignments 1–D and 1–E, for similar specialized handling,

What the American Railroads Need To Do To Remain in Business

By John W. Barriger
President, Chicago, Indianapolis & Louisville Railroad

The indispensability of railroads is unquestioned. This basic fact completely *assures* the permanence of their physical existence but only adequate earning power *will insure* the continuation of their present status as privately owned and managed business enterprises. The latter requires sufficient net railway operating income to validate the existing investment, through a fair return to the holders of the securities representing it, and also to generate the new capital funds continuously needed for replacement and development of railway property.

The railways are finding their earning power increasingly exposed to many adverse influences. Principal among these are the rapid erosion of traffic by subsidized competitive agencies of transportation, the inflationary forces of the day arising from the current political alliances between politics and labor, and the mounting demands of the tax gatherers.

Railway history covers a span of 125 years. From the outset its progress has been based upon improvement in the design, construction, maintenance and use of the manifold things which these carriers use to move man and the products of his work overland with constantly improving dependability, economy, safety, and dispatch. These underlying technical advances primarily represent the contributions of engineering and technology to railway development.

Every Business Has a Constant Struggle

Every business has a constant struggle to keep the volume of its output and the level of its selling prices in proper balance with its operating expenses which are fixed by the quantities of labor and materials used in production and the unit costs of each. It is nothing new for railway management to find itself squeezed between these factors but it is not alone among the industries in having worries of this nature. The railway problem only appears to be the more difficult one because it is so widely publicized by the procedures through which its selling prices and wages are established since these must be conducted in a gold fish bowl.

No one here doubts the ability of railway management to continue to solve its current and future problems in precisely the same way in which it has surmounted similar predicaments time after time throughout the entire period of its life. Engineers and technicians will continue to provide management with the improved plant, equipment and facilities that will permit a higher standard of service to be produced with less expenditure of labor and materials. It is your assigned duty first, to design, then to build and later to maintain the myriad components of the better railroads that are needed.

We must all constitute ourselves "vice presidents in charge of what shall we do tomorrow" to translate sound visions of future necessities and opportunities into practical realities.

The epitome of the century and a quarter of American railway development has been the constantly advancing economy with which labor and materials have been utilized. If this curve had ever stopped rising but instead had reached a ceiling and stayed there, American railway progress would have ended then and there and private ownership and operation of the carriers would have gone down soon after. Fortunately the railways' present status is safe for the protection and development of themselves and this nation as long as their managements push operating efficiency and service standards upwards

Chairman Blackman: Mr. Walker was also chairman of another subcommittee, and did some good work for our committee in compiling an index of the best work of our committee. This index, which the committee prepared on its own initiative, appears on pages 119–124. I think you will find it helpful.

Assignment 6—Cost of Railway Transportation and Operation Over the Past 100 Years; Principal Controlling Elements and Economic Significance, R. L. Milner (Chesapeake & Ohio), subcommittee chairman.

Mr. Milner: The substance of the report is portrayed by a chart and tables showing national income and railroad revenue freight ton-miles. The report indicates in a general way that freight ton-miles vary with national income, but that the increased revenue freight ton-mile per additional dollar (based on the dollar of 1926 purchasing power) of national income, has been in a general declining phase since 1920, whereas prior to that time it was in a rising phase. One of the reasons for that change has been the diversion of traffic to other transportation agencies. As more complete data measuring this diversion are developed, so that the trend may be analyzed, it may at such time be desirable to study its significance.

Chairman Blackman: Mr. Chairman, we will continue our report tomorrow morning.

Past-President Wilson: This is quite necessary in view of the scheduled excursion to the new central research laboratory.

The chair wishes to designate R. C. Bardwell and his associates as tellers to canvass the ballots cast for the officers of the Association for the ensuing year. The secretary will turn the ballots over to the tellers and the names of the successful candidates will be announced at the Annual Luncheon tomorrow noon.

(The meeting recessed at 4:00 p. m., and reconvened the following morning, March 15, at 9:05 a. m., in the Red Lacquer Room.)

(President F. S. Schwinn presiding.)

Chairman Blackman: Yesterday afternoon, Committee 16 presented four of the five subjects on which we were ready to report. Our last subject is Assignment 7.

Assignment 7— Yards; Effect of Their Location on the Economics of Railway Location and Operation, W. T. Rice (Richmond, Fredericksburg & Potomac), subcommittee chairman.

(In the absence of Mr. Rice, the report was presented by Herbert Ashton (Department of Commerce).

Chairman Blackman: Mr. President, our Assignment 3, reported on by Mr. B. T. Anderson (Union Switch & Signal Company) was to give a progress report on what he called the renaissance of the Chicago, Indianapolis & Louisville, otherwise known as the Monon. Our Assignment 4, on which we are not prepared to make report, has the title, Effect of Higher Speed on Railway Revenues, Operating Expenses and Charges to Capital Account. But, taking these two subjects together, we voted to ask the vice chairman of our committee, John W. Barriger, president of the Monon, to talk to us on the subject of Assignment 4, or, if he prefers, What the American Railroads Need to Do to Remain in Business. Mr. Barriger.

540 miles of line, has a $45,000,000 total investment to protect, and produced $18,000,000 gross revenues in 1949, compared to only $13,000,000 in the peak war year.

Railroads Owe Much to the Diesels

I have frequently stated in public addresses that it has been the diesel locomotive alone which rapidly produced the economies necessary to prevent the post-war inflationary squeeze from collapsing railroad earning power as happened in 1920–1921. There are 13,000,000 horsepower of diesel locomotives in the United States today. These represent an investment of a billion and a quarter dollars. Last year the railroad industry earned a little less than $700,000,000 net railway operating income. It is my opinion that nearly two-thirds of this earning power is directly attributable to the diesel locomotives and would have been lost without them. I state this as evidence that I am no mild enthusiast for the economics of diesels or what these locomotives will do. It is, however, from the vantage point of such a wholehearted disciple of diesel operation that I must emphasize that the improvement in operation and service and reduction in expenses which follows the substitution of diesel for steam power on lines with grades of 1 percent or over and sharp curves, must never blind operating and engineering officers to the still greater benefits which will follow the use of the same diesels on the same runs but over routes of better physical characteristics.

Let anyone here who thinks that diesels obviate improvements in route characteristics of lines consider the comparable train loads and unit operating costs for diesel locomotives on the light grade and heavy grade divisions of his own railroad just as I have sketched for you in reference to the Monon. The benefits of concentrating the power output of the diesel locomotive to build up speed and tonnage instead of dissipating it in battling the forces of gravity and the friction and speed restricting handicaps of curvature will produce economies of a dollar amount that will justify substantial equivalent investments to reduce grades to provide improved diesel performance. The mere fact that diesels can do much better than steam on an existing heavy grade line should not lead any railroad operating officer not to wish to achieve as promptly as sound economics of his existing situation will permit all of the benefits which go with running diesels over lines of superior route characteristics of grade and curvature. It would be worth investing a good deal of capital to raise the Monon's present 3300-ton slow speed train load limit on the southern portion of its line to the 8000-ton high speed potential obtainable on the northern end. Similar analyses can be found on the railroads of every person in this room. Diesels do wonders but they don't cancel out Isaac Newton's laws of gravitation. We all recognize the economic advantages of "Water Level Routes." Nature provided some railways with these great heritages of low grades but for those who were not bequeathed them for their main lines, build your own water level routes—with the aid of the many forms of modern equipment which permit dirt to be moved economically.

Higher Speeds Demand Many Improvements

Similarly curves which did not interfere with running of trains at the 45–70 mph. maximum speeds associated with most steam operations and so went unnoticed in the past now constitute real impediments to the sustained maximum speeds needed to provide the freight and passenger schedules required by present competitive conditions. These are easily obtainable with diesel power if physical characteristics of lines are improved.

The increasing tempo of modern train movement makes non-interlocked railway crossings as out of date as a mud road and signals must expedite and direct and not merely protect train movement.

to constantly improving levels. There never was a time when more improvements in methods, standards and devices and equipment were available for incorporation into railway operation than there are now and there probably never was a generation of railway managers more *able and willing to work* to utilize their opportunities to improve technical and operating standards and reduce unit costs of transportation. This certainly is an effective combination which insures success provided capital is continuously available to pay for the cost of the needed improvements.

A very much finer and more perfect plant will be required to enable the railways in near future years to render the kind of service that will attract traffic and at rates that will procure it, while paying prevailing standards of wages and still leave a margin of operating profit commensurate with the capital and credit requirements of the railways.

Diesels No Cure for Heavy Grades

Main line grades in excess of 0.5 percent are a great handicap to efficient operation; even with diesel locomotives. The latter materially reduce the cost of producing tractive effort and locomotive horsepower but the output of mechanical forces required to move a given train weight at an established rate of speed is the same whether the steam or a diesel engine is the prime mover. The improvement in operation and reduction in expenses which follows introduction of diesel locomotives in substitution for steam power on lines with heavy grades, (i.e., 1 percent and over) and sharp curves must never blind operating and engineering officers to the still greater advantages which will follow the use of the same diesel locomotives on comparable runs over routes with improved characteristics. Let anyone here who thinks that diesels obviate improvements in the route characteristics of lines stop to consider the comparable train loads and operating costs of diesel locomotives on the light grade and heavy grade divisions of his own railroad. The benefits of the former translated into unit costs and total economies and service benefits and capitalized in relation to traffic density will produce a substantial equivalent additional investment that can be justified to reduce grades to provide improved diesel performance.

It is just three hundred miles between the freight terminals used by the Monon in Louisville and at the outer edge of the Chicago Switching District. The physical characteristics of the terrain which it traverses between them is divided at the exact midpoint into flat prairies to the north and rugged hills to the south. As a result of this geographical condition, the northern half of Monon's main line has very favorable physical characteristics while those of the southern portion embody the heavy grades and sharp curvatures usually associated only with trans-mountain routes.

The Monon uses a 4500-horsepower diesel as its standard freight locomotive. On the southern half of the line, tonnage is limited to 3300–3500 tons and the almost unbroken succession of speed restricting curvature holds the average speed of the train to limits that handicap the provision and maintenance of fast freight and passenger schedules. On the northern half of the line, 8000-ton freight trains and maximum length passenger trains can be easily run at speeds approximating maximum authorized limits.

No one is a more ardent believer in the economics of the diesel locomotive than the Monon and I. The Hoosier Line was the first Class I railroad to become 100 percent dieselized and this transition took place within a relatively short period of time. If it hadn't been, this railroad would have followed the Fort Smith & Western and the Missouri & Arkansas to whatever place good railroads go when they die, but it is, as I hope you know, very much alive and on the high road to prosperity through rapid rehabilitation of its property and service standards and morale and public relations. A grand total of 80,000 diesel horsepower in 57 locomotives did this for a railroad which operates

organization will be of growing interest and importance to the entire membership of the American Railway Engineering Association.

Chairman Blackman: Mr. President, that concludes the report of Committee 16.

President Schwinn: Mr. Blackman, your committee has presented some very valuable and interesting reports, and Mr. Barriger's address has given us much food for thought. Does anyone in the audience care to discuss any part of this report?

W. J. Burton (Missouri Pacific): I very much approve of what Mr. Barriger has said, but I am tempted to ask one question, just to keep the record straight. He mentioned two railroads which have gone out of business—the Missouri & Arkansas, and the Fort Smith & Western. The question is, does Mr. Barriger think the use of diesels would have saved either of those railroads?

Mr. Barriger: That is a very good question. I really don't know. But I do know this: That the Monon would have perished without complete dieselization, and I made reference to the Missouri & Arkansas and the Fort Smith & Western not so much that they would have been saved if they had had an opportunity to follow our path, but rather that if we hadn't done as we did, with the diesels, we would have certainly gone down along with them. On our 45 million dollar property last year, through the diesels, we showed a net railroad earning power of a million and a quarter, after we had put in more than one million dollars in excess maintenance, over and above normal requirements. So we figure we have around two and a half million dollars normal net railway operating income on an investment of about 45 million dollars. Right now we have our earning power on a self-sustaining basis.

I am confident the diesel locomotive will inject power into any railroad to the extent of about 25 to 35 percent of its investment in diesels. However, I didn't mean to use this opportunity to make a sales talk for diesels. Privately, however, I believe that if those two other railroads had dieselized—of course, they passed out before they could have done this—they would have been saved.

S. E. Shoup (Kansas City Southern): I am quite familiar with both of the railroads that were mentioned. It is my opinion that diesel power will not save railroads that don't have adequate earning capacity, and those railroads, because of lack of traffic and connections had no prospects. I am sure that is the answer to the question.

President Schwinn: Thank you very much, Mr. Blackman. Your committee is excused.

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 243-286.)

(President F. S. Schwinn presiding)

Chairman R. K. Johnson (Chesapeake & Ohio): We have assignments on ten subjects and we are reporting on nine of them. While we have no report on Assignment 1, Revision of Manual, Assignment 2, does carry some Manual work.

Chairman Johnson then introduced the various subcommittee chairmen, in turn, who presented their reports.

Assignment 2—Motor Cars, Trailer and Push Cars, S. E. Tracy (Chicago, Burlington & Quincy), subcommittee chairman.

Mr. Tracy: The material now in the Manual, pages 27-1 to 27-8, inclusive, covers the recommendations of your committee over a period of about 20 years. Revisions have been made from time to time, but improvements in design and experience in the field have again made revision necessary. Part of the present material in the Manual is obsolete and should be deleted; part of it should be revised to bring it up to date; and part of it is satisfactory.

Signal and communicating systems must be designed for complete flexibility of train movement without noticeable train delay with the minimum mileage of sidings and additional main tracks consistent with the train density of the route. Continuous communications must be maintained between trains and dispatchers and between the locomotive and the rear end of every train. Main line turnouts and crossovers regularly used by road trains must be safe and comfortable for running through them at not less than half of the authorized normal speed of the route into which they are incorporated. All cars in general service must be adequate for inclusion in trains of maximum weight and speed and be well adapted to the reasonable necessities of the patrons of the freight and passenger services. Terminals of locomotive runs should be the same as of the trains which they haul and the intermediate servicing of motive power be held within the time limit and place of the stops for traffic purposes and crew changes.

With comparatively few exceptions, considering the country as a whole, the rail approaches to all cities, large and small alike, are littered with railway and highway crossings and a multitude of operating restrictions of many types and causes. These conditions seriously impede speed and flexibility and capacity of movement and dissipate the benefits of improved running over the rest of the line. Such conditions cry out for correction.

Like degrees of improvement must follow hand in hand in the facilities, tools and methods which the maintenance and the non-operating departments use. Office equipment and procedures require as close and effective consideration as the more spectacular features of railway work.

While the best American railway standards and practices are very high and are entirely adequate, too small a proportion of the entire main line mileage is developed to be all inclusive of these optimum conditions. Solution of the railway problem necessitates that all main line mileage should be improved to permit continuous high speed operation of trains of maximum length and weight. We might well pause to reflect that the single field of railway engineering in which one goes to Europe to see the most advanced and daring developments is in tunnel construction. American railways crossing the eastern and western mountains need long tunnels even more than the lines which cross the Alps.

Such developments as these are the primary ingredients of successful railway operation in this new decade and half century. Such a general prescription as that outlined herein will invigorate the railways and restore substantial volumes of freight and passenger traffic and permit their revenues to advance apace once more with the growth and development of the nation. When the standards envisioned in these remarks are achieved, the rail carriers will surmount all of the economic and political difficulties which beset them. Their revitalized physical condition will establish a firm foundation on which they will build to new heighths of service standards and financial stability. There they will be permanently secure in their private status and form an enduring bulwark of strength of the American way of life which can only be retained by protecting the institutions of private management and private property which created these railways.

The goals which the railroads seek can only be reached through further achievements in railway engineering and technology. The challenges were never greater and more stimulating and the opportunities never larger than now for the membership of this great Association to contribute in increasing measure to railway progress.

The close association between the functions of Committee 16 and the program which has just been outlined lead those who serve on it to believe that its work in this

it is well known might be likened to rescinding a law against murder simply because most people know that murder is unlawful. One effective method of obtaining general observance of regulations of any kind is by constant repetition and insistence that they be observed.

While this set of instructions represents a cross section of the rules and regulations for the care and operation of automotive equipment which are now in effect on many railroads, it is neither the intention nor the desire of this committee to establish a standard set of rigid regulations, with the expectation that each railroad will adopt them as herein presented. On the contrary, the object is to submit them as a guide only, with the expectation that they will be helpful to any railroad wishing to formulate such a set of instructions or, possibly, revise its instructions now in effect.

These instructions are set up in a manner similar to long-established motor car rules. Each paragraph is numbered so that, in case of rule infractions, ready reference may be made to the rule in question with no misunderstanding.

Assignment 7—Equipment Form to Accompany Purchase Proposal, W. F. Kohl (Southern), subcommittee chairman.

Mr. Kohl: By requiring all suppliers of roadway machines and equipment to fill out and submit, along with their bids, a form listing all the important items of specifications, including capacities and dimensions, it is believed that uniform information can be obtained. This will prevent the suppliers from substituting lighter or inferior equipment and presenting it as being equivalent to that which is called for in the purchase proposal. It will also allow the prospective purchaser to make a more accurate comparison of the item offered for sale by the various bidders.

The forms included in the report are representative, to be used as a guide, and do not cover all machines for which such forms might be desirable.

Assignment 8—Devices for Warming Engines to Expedite Starting Equipment in Cold Weather, A. W. Munt (Canadian Pacific), subcommittee chairman.

Mr. Munt: In compiling this report, your committee has attempted to describe the various types of engine heaters available, their general application, and the results they can be expected to produce under varying temperatures.

The starting of internal combustion engines in the field during cold weather is a problem that many railroads must contend with, and one which often involves expensive delays and damage to the equipment. With this thought in mind, your committee has endeavored in the report to acquaint those concerned with the devices that can be used for reducing the starting time of engines in cold weather, and thus effect greater utilization of the equipment.

Assignment 9—Off and On Track Equipment and Tools to Maintain Equipment of Mechanized Gangs, A. H. Whisler (Pennsylvania), subcommittee chairman.

Mr. Whisler: Our present report is closely related to, and can be considered as a continuation, or projection, of the report on Organization, Machinery and Tools for Repairing Maintenance of Way Work Equipment, as recorded in Proceedings, Vol. 47, 1946, pages 182–192, dealing with central shop repair of maintenance-of-way machines.

If used as a guide to equip each gang properly, it will reduce, if not eliminate, the unproductive time and confusion normally resulting from minor failures of the machines and equipment used by mechanized gangs.

In view of these facts, and the complications which would arise in trying to keep the various subjects in their proper sequence when adding to them, it is the recommendation of the committee, and I offer a motion, that all of the material now in the Manual on pages 27–1 and 27–3 be deleted, and that the material shown on pages 244, 245, 246 in our report, and to the end of numbered paragraph 3, "Warning Device" page 247, be substituted therefor.

(The motion was seconded, put to a vote and carried.)

Mr. Tracy: There are some corrections and additions necessary in the drawings on pages 27–2, and 27–4 to 27–8, inclusive. These are shown on pages 247 to 252, inclusive. I move that these corrections and additions be made to the present Manual material.

(The motion was seconded, put to a vote and carried.)

Assignment 3—Spray Equipment to Control Vegetation on Track and Right-of-Way. M. C. Taylor (Louisville & Nashville), subcommittee chairman, presented the report and described briefly the operation and use of the various types of spray equipment covered in the report.

Assignment 4—Power Mowing Machines and Desirable Attachments, L. E. Conner (Seaboard Air Line), subcommittee chairman.

Mr. Connor: This subject is closely related to, and may be considered as a continuation of, a previous report on mowing machines, submitted in 1944. This previous report did not cover attachments for mowing machines, but did illustrate and describe most of the mowing machines that were then available. Since that time, a heavy-duty, truck-mounted mowing machine, and a weed eradicator, known as a weed whipper, have been developed and are available for use. Both of these machines are described and illustrated in our current report.

Assignment 5—Devices for Loading and Unloading Roadway Equipment, was presented by R. E. Berggren (Illinois Central), subcommittee chairman, who outlined briefly the contents of the report.

Assignment 6—Instructions for the Care and Operation of Company Owned Automotive Equipment, N. W. Hutchison (Chesapeake & Ohio), subcommittee chairman.

Mr. Hutchison: One would suppose that in view of the great number of automobiles in use in America, the millions of licensed drivers, the mechanical aptitude of many of the drivers, the rigid driving regulations of the various states and cities, and the many programs designed to promote safety on the streets and highways, a list of instructions such as this would be wholly unnecessary. However, when one considers the great number of traffic accidents, and observes the poor condition of many of the vehicles on our highways, it is apparent that too much stress cannot be placed upon the importance of continuously bombarding the driving public with the necessity for maintaining their vehicles in first-class condition, and for observing the rules and regulations designed to minimize driving hazards. The fact that many persons do not give their own automobiles proper care and, in addition, seem to have little regard for their own safety and the safety of their fellow men, makes it obvious that there is a human tendency for most persons to pay less attention to company-owned property, unless they are forced to do so by a set of company instructions, the infraction of which may be followed by disciplinary action.

Many of the instructions contained in this report are elementary and are well known by most drivers of automotive vehicles. However, being familiar with instructions, and observing them, are two different things. To fail to include a rule because

We are no longer living in the motor car era and what may have been considered satisfactory for that day is not satisfactory in this machine age of expensive and complicated work equipment. We can no longer afford to place the responsibility upon a "handy man" with little or no supervision.

The use of maintenance of way work equipment has increased tremendously in recent years, and, as a result, many roads now find themselves with a large investment in work equipment, but with insufficient trained supervision to look after it.

During 1949, $17,500,000 was spent for work equipment by the railroads. In 1948 the amount spent was $18,700,000. The total for the ten-year period 1940 through 1949 was about $143,000,000; indeed a large investment. It would be interesting to have similar information to show the amount spent for additional supervision to protect this investment, but we know that it is not enough.

It would be interesting also to know what has been spent for shop facilities and forces, both on line and in the shop, to maintain this equipment. We know too that this is far short of requirement.

Special machines and tools are needed to completely overhaul maintenance of way work equipment, the majority being similar to tools and machinery used in repair shops operated by equipment dealers, bus and trucking companies or others specializing in the repairs to equipment operated by gasoline and diesel engines. Skilled mechanics, trained in the maintenance of this type of equipment, are necessary. Shops equipped with the necessary facilities along with trained mechanics, are available on but a few railroads today.

Let's consider the situation with respect to the increased use of diesel locomotives. It was found that the facilities formerly in use to service steam locomotives were not suitable to service the diesels, so shops and facilities tailored to suit the diesel locomotive were installed. Existing and additional supervision was likewise authorized to care for this new type of equipment. While the total investment is much less, is it not reasonable to assume that the situation should be similarly handled where work equipment is concerned?

Success in adaptability of new machines and in utilizing work equipment to its maximum capacity is one of the functions of, and is dependent upon, the adequacy and efficiency of the supervision. Along with the increasing number of units purchased, and the investment in these facilities, the necessity for fully utilizing work equipment has been further accentuated by the advent of the five day week, and the resulting increase in the cost of labor. Each machine represents a cash investment and in order to get any return on this investment, it must work a definite number of days.

Equipment Must Not Remain Idle

Equipment must not be permitted to remain idle for long periods as a result of abuse, the lack of a work program, or the lack of essential facilities and trained men to make repairs. In these days of low earnings and restricted forces, let us illustrate our point. Suppose you hired a man at a fixed salary, to be paid whether he worked or not. You would certainly so plan his work that he would have little idle time. If a machine is idle, you are losing money just as surely as though your hired man loafs on the job. If a machine is being operated inefficiently, you not only are losing money invested in the machine, but a portion of the wages paid to its operator as well.

The many benefits to be derived from the investment in work equipment and its intensive use are lost unless there is an adequate and suitable organization to supervise its operation and maintenance. Investing huge sums in work equipment and then failing to provide an organization to supervise it may be likened to buying an ocean liner and failing to provide a captain and other officers.

Assignment 10—Devices for Unloading Cross Ties, E. L. Anderson (St. Louis-San Francisco), subcommittee chairman.

Mr. Anderson: To date there has been scarcely any development along mechanical lines to assist in the handling of cross ties out on line of road. There has been some development for the handling of ties used in yard tracks, and also in storage yards, the latter of which are not being considered in this report. Such details as are available are presented in our report.

With the necessity for more efficient labor and a reduction in the expenses of handling ties, it is recommended that serious consideration be given to the further development of devices for the handling of cross ties on line of road.

Chairman Johnson: Mr. Edgar Bennett of the Southern Railway, and previous chairman of Committee 27, will now present a short talk, in which all of you who are connected directly or indirectly with the use of work equipment will be interested.

Organization Needed To Handle Work Equipment

By Edgar Bennett

Chief Engineer, Maintenance of Way and Structures, Southern Railway System

Your committee was requested to bring before this meeting of the Association, a subject embraced in its activities, having combined constructive merit and interest for consideration and discussion. We have chosen the important question of "Organization Needed to Handle Work Equipment."

Committee 27—Maintenance of Way Work Equipment, of this Association, has been entrusted the important duty of keeping you informed about the equipment and tools that are now available, what they will do when properly organized and operated. Also new equipment and tools that are needed to advance and improve the maintenance work of the railroads.

Organization to correctly manage the use and repair of maintenance of way work equipment is essential if economy is to be realized from the equipment. We are indeed, glad of this opportunity, to stress again, the need of ample organization, with the hope that you who are charged with this responsibility will see that equipment placed under your direction is efficiently handled to produce expected results.

The Track Motor Car

The most common type of work equipment originally used in maintenance of way departments on American railroads was the track motor car, consisting simply, in its earliest stages, of a gasoline engine mounted on a hand car frame. A great many of these engines were purchased by section foremen at their own expense or the cost was shared by the other members of the force. The railroads also, of course, bought many such engines and had them installed on lever cars. Later, a complete motor car was built and marketed.

Where a foreman had invested his own money in a motor car engine, it was only natural for him to see that the engine was given good attention and, most generally, the foreman himself maintained it. Originally, the foreman also maintained the company-owned engines and motor cars but later, due to increase in number of these units and lack of knowledge by some foremen, a "handy man" in some force was charged with this responsibility and, because of his special ability, was upgraded to a mechanic or maintainer. In many cases, the mechanical skill of this "handy man" was severely limited, producing varying results, but, because of the lack of skilled supervision, he was virtually his own boss.

under the title "Organization, Machinery and Tools for Repairing Maintenance of Way Work Equipment."

President Schwinn: I think Mr. Bennett's address has been most interesting and points up some possible economies we can all well consider on our respective properties. Mr. Johnson, the work of your committee is becoming increasingly important. We appreciate the quality and completeness of your several reports. The committee is excused.

Discussion on Economics of Railway Labor

(For Report, see pp. 307–340.)

(President F. S. Schwinn presiding)

Chairman H. E. Kirby (Chesapeake & Ohio): Committee 22 has arrived at an all-time high for its willingness to render any service which may enhance the work of the committee or the interests of the Association. Among its individual members of whom this might be said, one name comes immediately to mind; a man who has been a member of this committee since its inception, and who, a former chairman of Committee 22, was unanimously chosen by the committee to tell you something about its history, its work, and its achievements to date—George M. O'Rourke!

The Committee on Economics of Railway Labor, Its Conception, Aims and Achievements

By G. M. O'Rourke

Assistant Engineer Maintenance of Way, Illinois Central Railroad

I appreciate the courtesy shown by the members of Committee 22 by inviting me to address the Association this morning. My remarks are for the younger members and for those new members who may not be so young. You elder statesmen may take a five-minute nap.

The Committee on Economics of Railway Labor was conceived through a suggestion from the floor of the convention in 1916. Born a third of a century ago, it has grown into lusty manhood and stands in the front ranks as one of the most important committees in the Association. If there is any doubt in your mind about its import or significance, a study of the many interesting and instructive reports of this committee and a comparison of your payrolls and labor costs today with those of 1917 will remove such doubts. Or look over the 1950 list of assignments of the various committees and see if you can find any items which are not associated with labor economies, either directly or indirectly.

A Roster of Accomplishments

A brief outline of the past performances of our committee, and of the planning being done for our immediate and future operations, follows. Our scope includes all labor problems relating to construction and maintenance of roadway, track, bridges, buildings, water service, and miscellaneous facilities. As I present this outline, I realize that many of the subjects may not be fascinating to most of you. But I do want to ask that each of you pay close attention and ask himself the following questions with respect to each subject.

1. Is this subject important to me in my work?
2. Could I serve my railroad better if I knew more about this subject?

The type and extent of the work equipment organization and the facilities to repair the equipment must, of necessity, be based upon the amount of equipment owned and the total sum invested in it. The annual expenditure for such an organization, and such facilities, may readily be calculated but it is difficult to determine the far-reaching economies that may be effected by them. When it is considered that the annual charge against idle machinery for depreciation, interest, taxes and insurance, amounts to approximately 15 percent of the investment, it is certainly logical to appropriate a portion of this sum for supervision to see that the equipment is not allowed to remain idle. We should like to offer the following typical supervisory organization which may be modified to suit conditions on any railroad. However, whatever the extent of the organization provided, it should be given complete authority to coordinate all of the activities in connection with work equipment from, and including, its purchase to its retirement or, as we might say, "from the cradle to the grave," to insure that it is operated and maintained to achieve the maximum in efficiency and economy.

Superintendent of Work Equipment.—Should report direct to the engineer maintenance of way or corresponding chief maintenance officer. He should have general superintendence over all matters pertaining to work equipment and the work equipment organization. He should have full authority to enforce rules and regulations and sufficient personnel to obtain the desired results.

Engineer of Work Equipment.—Should report direct to the superintendent of work equipment. Will prepare equipment specifications; establish standards for uniform practice; recommend suitable machines and organization for mechanized work; assign and schedule machines to fit work programs; observe and study new and existing machines; provide for maximum utilization of equipment; conduct tests of machines and appliances; and formulate and maintain suitable reports and records of work equipment.

Shop Supervisors.—Should report to superintendent of work equipment. Should be furnished with shop or shops fully equipped with necessary tools and machinery and properly manned so as to make complete repairs to work equipment; maintain adequate stock of repair parts for line-of-road and shop use.

Inspectors of Work Equipment.—Should report to the superintendent of work equipment. Make periodic inspection in the field of all equipment on his territory reporting conditions found; such as, equipment failures, idle equipment, and improper handling; program shopping of equipment and materials needed; check requisitions for machine repair parts stock on line-of-road.

Operator Instructors.—Should report to the superintendent of work equipment. Train and instruct operators in the operation and care of work equipment and methods of use.

Supervisors of Work Equipment.—Should report jointly to district engineer, division engineer or corresponding maintenance of way officer on his territory. To be in direct charge of mechanics, or field maintainers, and operators. Program use of work equipment, prompt repairs, transfer of machines and enforce rules and regulations.

This talk concerns itself mainly with the supervisory end of a work equipment organization for which reason the duties of the work equipment mechanics and operators have not been included. However, keeping a machine in service and operating at maximum capacity is directly dependent upon the skill and competence of its operator and the mechanics. These men are definitely an important part of any work equipment organization.

For further information relative to a suggested work equipment organization and the facilities for maintaining work equipment, we refer you to a report prepared by this committee which is found in the AREA Proceedings, Vol. 47, 1946, pages 182 to 192,

Maintenance and operation of the railroads are carried on through the supervised and economical use of men, machines and materials. The most valuable of the three is men. The conservation of human resources, or "humangineering," is constantly before this committee, recognizing that safety and efficiency are inseparable in practice and in fact.

In a long service it has been my privilege to know more or less intimately all of the chairmen of Committee 22. Looking backward from Chairman Kirby, I recall many whom you will recall; J. S. McBride, H. A. Cassil, Lem Adams, A. N. Reece, C. C. Cook, C. E. Johnston, and H. R. Safford. One came up from the "Heart of Texas," donned his spurs and rode herd so severely he became known to us as "Simon Legree." His real name was Fred S. Schwinn, president of our Association.

Among the most valued of gifts bestowed by the passing years is the memory of pleasant relations with those we serve. The members of Committee 22 have many such memories and I am truly gratified to recall some of them in this brief review of our activities over the years in behalf of this Association.

President Schwinn: Thank you, Mr. O'Rourke, for a very interesting review of the work of Committee 22.

Chairman Kirby then introduced, in turn, the several subcommittee chairmen, who presented the committee's reports.

Assignment 1—Revision of Manual, N. D. Howard (Railway Age), subcommittee chairman, called attention to the proposed revision of the material in the Manual under the heading, Housing Maintenance of Way Employees, and moved the adoption of the new material submitted.

(The motion was seconded, put to a vote and carried.)

Assignment 2—Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work, C. W. Reeve (Delaware & Hudson), subcommittee chairman.

Mr. Reeve: For many years Subcommittee 2 of Committee 22 has endeavored annually to study a maintenance operation that has resulted in a substantial saving in labor on some particular railroad. In 1949, anticipating the 40-hour week, coupled with an increase in track labor costs, it was decided to give members of the Association the benefit of a study of mechanized methods of roadway and track maintenance.

When it was decided to make this study, the committee turned immediately to the Pennsylvania Railroad, knowing that this railroad has effected large economies through the use of power tools and machines. When the Pennsylvania was approached, the officers of that company graciously told the committee that not only could such a study be made of their methods, but that they would do everything possible to cooperate with it. Their cooperation was oustanding. Not only did they make available considerable data, but they entertained almost the entire membership of Committee 22 on a two-day inspection trip over the Pennsylvania. The first day the committee assembled at Broad Street Station, Philadelphia, and entrained for New Brunswick, N. J. From New Brunswick, by busses supplied by the Pennsylvania, the party was taken to a number of locations along the right-of-way where they were shown how the economies were being effected that are listed in the report of the committee.

The following day the committee was taken by special train, with a unique open-end inspection car, from Philadelphia to Pittsburgh. This was a most informative and instructive trip, I assure you. Opportunity was given the committee to see a number of different types of mechanized methods in practice. Not only did this trip show the

The organization and qualifications of supervisory forces; recruiting, training, educating, rules governing, examination and economic ratio.

The recruiting, training and educating of other labor; technical and nontechnical, skilled and unskilled.

Study of the ways to stabilize labor when earnings fluctuate. Like Mark Twain and the weather, everybody agrees that stabilization of railway labor is desirable and becoming more so with the passing of time, but nobody has been able to tell us how to do it when railroad earnings go up and down from month to month.

Housing and feeding or boarding of labor.

Time studies, methods of performing work with labor saving equipment and economical labor force organization.

Composite effect of new or improved materials, equipment, practices, programming and force organizations.

Effect upon labor of increased track loading or impact, increased speeds, and modern rolling stock.

Labor practices on foreign railroads.

Under the head of statistics, studies are made of the average manhour equivalents, recommended units of measure of work performed, methods for keeping cost data on labor operations, equating facilities for the purpose of distributing labor, and the effect of the shorter work-week.

On-the-ground studies of and reports covering practices on individual American railroads that have made notable progress in the economical utilization of labor have taken the committee to many parts of the country.

Studies to date have been made on the

Lehigh Valley
Norfolk & Western
St. Louis Southwestern
Burlington Lines
Chicago, Rock Island & Pacific
Central of Georgia
Great Northern
Illinois Central
Denver & Rio Grande
Delaware & Hudson
Delaware, Lackawanna & Western
Pennsylvania R. R.

These have all involved field inspections, often by special train and have covered economies in labor derived through the use of methods and materials, such as:

Stabilization of the roadbed by improved surface drainage, subdrainage, pole driving and bank widening.

Better types of ballast and ballast cleaning.

Treated ties; improved treatment of ties; larger ties.

Use of tie plates and methods of fastening to ties.

Heavier rail; welded rail; methods of anchoring rail.

Improved joint bars; methods of lubricating.

Better organization of maintenance forces; specialized gangs; large gangs with traffic detoured; improved supervision and esprit-de-corps.

Track inspector, or supervisor system, to enable gangs to devote full time to productive work.

Increased mechanization and increased intensity of use of work equipment-on-track and off-track equipment.

Use of trucks on highways.

Methods of handling snow and snow melting devices.

These studies have been definitely stimulating and informative, and will undoubtedly tend to enliven and broaden interest in the work of the committee in the future.

Discussion on Ties

(For Report, see pp. 211–214.)

Chairman B. D. Howe (Louisville & Nashville), introduced, in turn, the several subcommittee chairmen, who presented the committee's reports.

Assignment 2—Extent of Adherence to Specifications, P. D. Brentlinger (Pennsylvania), subcommittee chairman, was presented by title only.

(Vice-President H. S. Loeffler assumed the chair)

Assignment 3—Substitutes for Wood Ties, L. P. Drew (Union Pacific), subcommittee chairman.

Mr. Drew: In developing data for this report, it was interesting to note that during the past 40 years no satisfactory substitute has been found for the wood cross tie. It is further evident that the urgent necessity for such a substitute has ceased to exist. This change has been brought about by the increase in the life of the wood tie by preservative treatment and the reduction in wear of the tie by better track fastenings, heavier rail and larger tie plates. However, the subject is by no means a dead issue. Rather, it is a definite challenge to American inventive genius to evolve a substitute for the wood tie, which is still supreme.

Assignment 4—Tie Renewals and Costs Per Mile of Maintained Track, was presented by Chairman Howe, who was also chairman of the subcommittee handling this assignment.

Assignment 6—Bituminous Coating of Ties for Protection from the Elements, R. W. Cook (Seaboard Air Line), subcommittee chairman. In the absence of Mr. Cook, C. D. Turley (Illinois Central) presented the report.

Mr. Turley: The bituminous coating of ties for protection from the elements is not a new idea. But further developments are being made in coatings for application to the top surfaces of ties, which are exposed to the weather. This has not been an active subject in the past, due perhaps to the fact that labor was relatively cheap, materials were plentiful, and there was no outstanding saving in such a process. However, in more recent years the price of labor has increased out of all proportion to the cost of materials. In the case of cross ties, labor costs, perhaps, have increased as much as ten times, while the cost of ties has increased probably 2½ times.

A number of tests of coated ties are now in existence, and more tests will be installed in the year ahead. This committee feels quite confident that these tests will show a substantial saving through the application of coatings.

Chairman Howe: We are making no formal report on Assignment 5—Methods of Retarding the Splitting and the Mechanical Wear of Ties, Including Stabilization of Wood, Collaborating with the NLMA. You will recall that at last year's meeting, Mr. R. S. Belcher of the Santa Fe made a rather thorough report on the research work being done under this assignment, under the direction of this committee. I shall ask Mr. G. M. Magee, research engineer, AAR, who is associated with this project, to bring us up to date on what has been done.

committee how the work was being done, but the committee also had an opportunity to see the results of much work that had already been accomplished.

In analyzing the statistics and facts presented in our report, there are several things to bear in mind:

1. Mechanized equipment is useless unless it is used. A power tamper standing idle in the tool house is just like a trackman sitting all day alongside the track, yet still drawing his pay. The return on the investment in any machine varies directly with its use.

2. The more careful the planning for the use of work equipment, the greater the economy realized.

3. Mechanized equipment must be efficiently and properly maintained.

4. The correct tool must be selected for the job to be performed.

In conclusion, I would direct your attention to just one fact. This study showed that, for every $1000 invested in work equipment, the Pennsylvania has saved 3560 man-hours of labor.

To a very large extent, the future of the entire railroad industry depends upon the ability of its engineering officers to lead the way in the finding or developing of efficient mechanized methods of track maintenance.

Assignment 3—Organization of Forces for Track Maintenance Operations. (Chairman Kirby, who was subcommittee chairman on this assignment, presented a brief synopsis of the report.)

Assignment 6—Labor Economies of Various Types of Foundation Under Railroad Crossings, J. B. Clark (Louisville & Nashville), subcommittee chairman.

Mr. Clark: While your committee cites labor economies effected by the use of each of the special features in crossing foundation design discussed in its report, it is our hope that by continuing this assignment, additional reports will be made by maintenance officers possessing still more definite information on the subject, which will enable your committee to make a more conclusive report than has thus far been possible.

We are encouraged by reports that some roads are actually making comparisons of the labor cost of maintaining crossings before and after changing the foundations under them. We will be glad to get these reports when the studies are concluded.

Assignment 8—Meeting Conditions Imposed by Shorter Work Week, J. S. McBride (Chicago & Eastern Illinois, retired), subcommittee chairman.

Mr. McBride: Last summer, after the 40-hour week agreement had been reached, the Committee on Outline of Work assigned this subject to this committee for study and report. In handling the assignment, your committee has endeavored to ascertain the application of the 40-hour week agreement in the maintenance-of-way department and what steps have been taken, will be taken, or are considered necessary, to offset the increased costs of the shorter work-week.

The committee would like to take this opportunity to thank the roads for their splendid cooperation in furnishing the information necessary to make this report possible in so short a time. The committee received replies to its query from 64 railroads, operating some 226,000 miles of road. Most of the replies were in considerable detail, indicating a great deal of effort by these roads.

(Mr. McBride then read the conclusion presented in the report.)

Chairman Kirby: That concludes the report of Committee 22.

President Schwinn: Mr. Kirby, we have always looked to Committee 22 to bring in an interesting report. We have not been disappointed here today. We give you the thanks of the Association.

tically with 10,000 lb. outward. This represents perhaps the average maximum loading on the tie plate that would be developed in the track.

In the next series of tests, water was added to the tie plate, being dripped into the spike holes, and after 1,800,000 cycles of loading there was ¼ in. wear into the tie. The appearance was similar to a plate-cut tie in track.

This laboratory test in conjunction with the work of the Teco Laboratory indicated very clearly that moisture between the tie plate and the tie has a very important part in the rate of tie wear. Whether this wear is due to softening of the wood fibers or to lubrication on the surface so the tie plate moves more laterally under the horizontal loading components, we do not know at this time.

I would like to mention briefly another phase of the work in connection with the reduction in splitting. Studies made during the seasoning of ties indicated that most of the splitting occurs during the seasoning period of the ties in the yard. By the time the ties go into the plants, most of the splits have developed. This makes it obvious that any real remedy for checking and splitting must be applied soon after the tie is cut—as soon as possible. Accordingly, they have started work on developing a new method of treating ties, using a chemical which will attract water, which is added to the creosote solution, so that in one process in treating green ties, the water is removed from the wood cells and is replaced with the treating solution.

The considerable experimental tests on this method of treatment have shown it to have possibilities. If this method proves practical, it will be a valuable treatment because it will enable us to dispense with the seasoning period, while at the same time precluding the checking and splitting of ties.

The work at Teco also involves efforts to produce a laminated tie, and studies of bituminous and other coatings on the tops of ties already in track, which may have started to develop cracks or splits, for the purpose of filling these and preventing them from progressing further.

Summing up, what we hope to accomplish in this work is to develop a method of treating ties in which the tie can be taken green, without any seasoning, and adequately treated without the shrinking and stress which cause checking and splitting. Then, in order to eliminate mechanical wear, develop methods that will hold the tie plate firmly to the tie, and also seal out moisture from between the tie plate and the tie surface. If all this can be accomplished in this research work, and it doesn't appear to be impossible, it seems that we should be able to extend the life of cross ties to 35 or 40 years.

Vice-President Loeffler: Mr. Magee is no stranger to this audience. Thank you very much, Mr. Magee, for your very interesting talk.

Chairman Howe: This completes the report of Committee 3.

Vice-President Loeffler: Thank you, Mr. Howe, for your informative and interesting report. Your committee is now excused with the thanks of the Association.

Discussion on Wood Preservation

(For Report, see pp. 343–361)

Chairman G. B. Campbell (Missouri Pacific) introduced, in turn, the several subcommittee chairmen, who presented the committee's reports.

Assignment 2—Service Test Records of Treated Wood, A. J. Loom (Northern Pacific), subcommittee chairman.

Mr. Loom: In my estimation, many service tests of cross ties and other treated materials have been made, and are still being conducted, by various railroads, that have

Status of Research on Cross Ties

By G. M. Magee
Research Engineer, Engineering Division, AAR

As you gentlemen know, the increase in price of cross ties since the war has made this one of the most important items in maintenance-of-way expenses. This has been recognized by everyone. If we are to get our operating costs down to where the railroad industry can continue a profitable operation, something must be done about this item.

Recognizing this, under the sponsorship of the Committee on Ties, an agreement was entered into with the National Lumber Manufacturers Association two years ago for a cooperative research investigation for the purpose of prolonging the life of cross ties. It was the original intention that this project would take about five years. It now has been underway approximately two years. Considerable headway has been made, but certainly we haven't as yet found the answer.

I would like to mention briefly some of the more promising lines that the research has developed into. The first undertaking was to have one of the laboratory technicians make rather extensive studies of used cross ties being removed from track. Representative ties were selected and sent to the Teco laboratory at Washington for examination by their wood technologists. Generally speaking, there has been very little evidence of decay found in the ties examined. Microstudies made of the wood fibers immediately under the tie plate area have indicated some crushing of the springwood cells, some buckling of the wood rays, and some lateral shifting of the wood rays. There was also some evidence that the moisture in contact with the wood, and perhaps containing some of the acids from the wood, was attacking the iron in the tie plate and taking it into chemical solution. This iron was, apparently, then turning around and attacking the cellular structure of the fibers in the ties and causing them to deteriorate and break down. The microstudies indicated, generally speaking, that the wood lost under the tie plate area is abraded away and completely gone.

There was also evidence in many of the ties that sand and grit penetrated down for some distances below the wood surface in the tie plate area. It was thought that it might be helpful to see whether this same type of breakdown of the wood cells could be brought about in the laboratory by applied loads, and, accordingly, wood was selected, both soft and hard, and was subjected to vertical loads in a tension machine in the laboratory. It was found in these tests that the same type of wood distortion could be produced, but the pressures required to do this were three to four times as large as the intensity of the tie plate loads we get on ties in the track. So, it seems quite evident something is involved other than just the mere direct pressures or intensity of pressure.

In conjunction with the work being carried on at the Teco Laboratory, the Ramapo-Ajax Division of the American Brake Shoe Company has designed and constructed a machine in its laboratory, in which a section of tie, with a tie plate, can be subjected repeatedly to approximately the same type of loading that the tie plate receives in the track, and a rather extensive series of tests is being conducted in this machine. Ramapo-Ajax is cooperating in our work at the Teco Laboratory and made this machine available for such use as we wish to make of it.

One of the most interesting things found with this machine was that, in the first test made, which was with a 14-in. tie plate on an untreated fir tie, there was no wear of any appreciable amount on the tie after 40 million applications of load.

Now, in the application of the load, each cycle consists of a 20,000-lb. load vertically and 5000-lb. load inwardly on the plate, and on the next cycle, 20,000 lb. ver-

Further experiments with urea in the seasoning of cross ties have not shown worthwhile advantage. The work on that, and on drying with special drying oil, is presented in the report.

Chairman Campbell: Mr. Chairman, that concludes the report of Committee 17.

Vice-President Loeffler: Thank you, Mr. Campbell, for this interesting report. Your committee is now excused with thanks from the Association.

Discussion on Roadway and Ballast

(For Report, see pp. 707–757)

Chairman H. W. Legro (Boston & Maine): Committee 1 has three reports to present to the convention. Included in the assignments are subjects, in the development of which opportunities are being discovered to realize unusually large and quick savings from moderate expenditure. Field and laboratory research in roadbed stabilization, being carried on with appropriations by the AAR, is producing results which have encouraged many railroads to proceed with confidence in programs that effect economies in maintenance beyond earlier reasonable hope. These studies are being continued and extended.

Assignment 1—Revision of Manual, A. P. Crosley (Reading Company), subcommittee chairman. In the absence of Mr. Crosley, the report was presented by G. W. Miller (Canadian Pacific), vice-chairman of Committee 1, who moved that all of the Manual material submitted for reapproval be adopted.

(The motion was seconded, put to a vote and carried.)

Assignment 2 (a)—Physical Properties of Earth Materials.

Chairman Legro: Assignment 2 (a), relating to the load capacity of the roadbed and allowable pressures, goes hand-in-hand with Assignment 6 (a), Roadbed Stabilization, and they together share in the research work being done under the direct charge of Mr. Rockwell Smith of the AAR research staff. The report on Assignment 2 (a) will be presented by J. W. Demcoe (Canadian National), subcommittee chairman.

Mr. Demcoe: Until 1945, this assignment was investigated from the theoretical point of view. It was then decided that the principles of soil mechanics should be applied to methods of stabilizing roadbeds where difficulty was being experienced in maintaining surface and alinement of the track. This necessitated obtaining pressures in railroad subgrades under moving loads; also the finding of the characteristics of various types of soils in service in both the field and the laboratory.

Two tests were investigated in 1948 as reported in Vol. 50:

(1) Soil pressure cells on the Chicago, Burlington & Quincy, near Red Oak, Iowa.

(2) Record was kept of the field observations and soil tests in connection with the construction of a relocated line near Grenada, Miss., on the Illinois Central, which was built under the latest methods of moisture and compaction control, for comparison with field performance when put into service.

A series of oscillator tests were also run at the University of Illinois. This machine is designed to apply simulated traffic loads to a small section of ballast and subgrade soil.

By correlating the same soils in field performance and accelerated laboratory tests, it is expected that this apparatus may be valuable in determining the rate and manner in which instability takes place in railroad subgrades. Experiments carried out show that subgrade instability is mainly produced by surface water, rather than by underground flow.

never been made available for the reports of our committee. In fact, some of the members of our committee have seemingly been unable to produce any service records from their own railroads. Our chairman, Mr. Campbell, has, therefore, suggested that we ask the secretary's office to address officers of the various railroads, explaining the need for their service test records for the use of this committee. It is hoped that additional information will become available so that we can include it in our next year's report.

Assignment 3—Destruction by Marine Organisms; Methods of Prevention, Dr. W. F. Clapp (Clapp Laboratories), subcommittee chairman. (This report was presented by title only.)

Assignment 4—Creosote-Petroleum Solutions, R. S. Belcher (Atchison, Topeka & Santa Fe, retired), subcommittee chairman.

(In the absence of Mr. Belcher, the report was presented by A. L. Kammerer (Consulting Timber Engineer), who moved that the Standard Volume Correction Table for Creosote-Petroleum Solutions, which appears in the Proceedings, Vol. 50, 1949, pages 378 and 379, be adopted for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Assignment 6—New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products, was presented by F. W. Gottschalk (American Lumber & Treating Company).

Assignment 7—Incising Forest Products, W. P. Arnold (Koppers Company), subcommittee chairman.

Mr. Arnold: The assignment given to this committee has to do with the perennial problem—what to do about hardwood ties, such as beech, maple, cherry, birch, etc.? The cause for premature failure of this class of tie, as you all know, has been due largely to splitting in a certain percentage of these ties, resulting in internal or mechanical failure.

One approach to the problem studied by this committee is the incising of such ties at the time of their receipt. Tests conducted over the past ten years have shown that such incising has greatly reduced the amount of splitting through distribution of the stresses across the surfaces of the tie. Some benefit has also been found in the further penetration of the preservatives into the wood. We were very much encouraged by our results. In fact, one eastern railroad is now adopting this type of procedure—the incising of all the C group ties when received at the treating plant. Experience during the past two years on this road has shown that it is very much worth while.

Additional tests have been reported by the committee. This year tests were conducted by the Great Northern between Floodwood and Wawena, Minn., and on the Minneapolis, St. Paul and Sault Ste. Marie. The Erie Railroad is also conducting tests.

Assignment 11—Artificial Seasoning of Forest Products Prior to Treatment, W. P. Arnold (Koppers Company), subcommittee chairman.

Mr. Arnold: The only new method of artificial seasoning which has come to the attention of the committee, was received after the preparation of our report. This new method is the one touched on by Mr. Magee in his report in connection with Committee 3—the addition of a chemical to the creosote solution to bring about both drying and treatment at the same time.

work, so that those who had not as yet tried roadbed stabilization, would have some basic information to go on. To that end, Mr. Smith has prepared and presented in his present report definite information as to how to go about roadbed grouting. We feel that grouting is only one of the cures, and we have tried to look into other known successful methods of stabilization. Again this year, therefore, Mr. Smith describes other methods, such as the driving of poles, sandfilled blast holes, sand piles, and while reference to these methods is not in detail, it at least presents the fact that there are ways of stabilizing roadbeds other than grouting.

Some of the grouting methods used are cheap and some are expensive. Pole driving, with which I am not familiar, is probably one of the least expensive methods where it is applicable, such as in very low fills and in wet pockets in cuts where the roadbed is of the right type. Where it can be used, I think, as a rule, it is cheaper than other methods. That is not always true. We have roadbed grouting that costs as low as 60 cents a foot, I think. The Santa Fe did some work at a cost of only 60 cents a foot.

Roadbed grouting does not always mean the same thing. From my observations I have found that on some railroads, roadbed grouting is a system of mixing grouting with underlying material. On others it is going down to the subsoils and attempting to stabilize. So, you can see, there might be many different ideas about grouting. We would appreciate very much, any sound criticism of the material Mr. Smith has prepared for you this year, and any suggestions you might have to offer in connection with our work.

Vice-President Loeffler: Thank you, Mr. Crosland. Your excellent report will be received.

Assignment 6 (b)—Construction and Protection of Roadbed Across Reservoir Areas, B. H. Crosland (St. Louis–San Francisco), subcommitee chairman.

Mr. Crosland: We have had many requests for material on this subject from those railroads confronted with the construction of roadbeds through reservoir area—due to the recent development of a dam construction, and your committee has been trying to develop something for you, as information, with the understanding that subsequent investigation may call for some changes.

Last year, we gave you some suggested roadbed sections that were not very specific, for the reason that we still had to have a good deal of work from our committee on soil and stabilization studies before we could go any further with these sections. We have had many requests as to the freeboard required on account of wave action under varying conditions. This is not a new subject. It has been studied for many years and many formulas have been developed. Unfortunately, because of varying conditions, these formulas often give wide variations. But we have attempted this year to develop a formula which we think is safe for use on inland waterways, including reservoirs, and hope it will be of use to you.

The United States Government is making actual tests with the equipment for measuring wave height, installed at various places, indicated in the report. As data are compiled, we may find that we will have to change our formula. But, we have checked the results of this formula against such known reports as are to be had, and we think it is safe to use in the absence of anything more accurate.

In our formula, mathematically, it looks as though we could have reduced the coefficient a little. We have a coefficient of 1.4 over 3. Now, the 1.4 is rather arbitrary. Sometimes, 1.5 is used. That is a coefficient to take care of the out-thrust of the waves when they come in contact with the side of the embankment. We could very easily use the 1.5 and reduce our coefficient to ½. If you want to use that in the formula, it will be all right.

Report of the research carried out during the past year is on pages 710 to 727. The results indicate that it is possible to obtain good records of subgrade pressures by pressure cells of the AAR design. Further investigation by this method of pressure in subgrades is required. The results obtained justify additional work, and it is believed that future research will yield information which will be of great value.

The second part of the report covering the Investigation of Stability of Compacted Embankments indicates that standard soil tests may be insufficient. This is one of the first, if not the first, investigation carried out on an embankment which was constructed in accordance with the latest compaction methods in layers by means of rollers, control of the water content of the soil, and to some extent, selection of the borrow material to eliminate particularly unstable soils.

The cost of constructing this fill by control methods was relatively great, but it did not lead to the results expected and high maintenance expenditure has been necessary to maintain the track located on it. The unsatisfactory behavior was found—and could only have been found—by making a minerological analysis confirmed by swelling tests.

This investigation was carried out on a fill on a line which was being relocated between Pottsboro and Sadler due to the construction of the Denison Dam on the Missouri-Kansas-Texas lines.

Studies and observations are being continued along similar lines at Coldwater and Grenada on the Illinois Central, and it is planned to carry out field studies of the behavior of fills for several years.

Study and research have been given to improving rail, tie plates, ties, ballast, and the so-called superstructure and substructure of railroad track, but little attention has been given to the foundation or subgrade.

We are carrying Cooper E 60 and 70 loads on subgrades where "soft spots" are occurring which are, in effect, good for only half that load capacity.

Thousands of dollars are being spent annually in propping up these locations, and it is being done without proper diagnosis. Before a cure can be effected or prescribed, it is necessary to find the cause of the ailment.

It is the opinion of this subcommittee that too little attention has been given to this fundamental problem of track maintenance in the past, for example, load capacities and allowable pressures on subgrades.

Vice-President Loeffler: Thank you, Mr. Demcoe, for this very informative report on an important subject. We shall be looking forward another year for more interesting details on this subject.

Chairman Legro: One of the fastest-growing developments in railroad maintenance is the stabilization of roadbed by various means. There is good reason for that. When properly carried on, it produces an improved foundation for the track structure and immediate savings in maintenance expense.

The report on Assignment 6 (a), Roadbed Stabilization, will be presented by Mr. B. H. Crosland, the chairman of the subcommittee on Roadway Formation and Protection. He will present also the report on Assignment 6 (b), Construction and Protection of Roadbed Across Reservoir Areas.

Assignment 6 (a)—Roadbed Stabilization, was presented by B. H. Crosland (St. Louis-San Francisco), chairman of Subcommittee 6.

Mr. Crosland: Last year you heard Rockwell Smith of the AAR research staff give us a nice talk on what had been done so far in roadbed stabilization, and we felt that the investigations of such stabilization had reached a point—had been in effect long enough—where we were in a position to make some definite recommendations for this

A Research Program on Chemical Herbicides for Railway Use

By Jack P. Taylor
Virginia Polytechnic Institute

Except for numerous articles on weed killers for agricultural use, an exhaustive search revealed no reported research on weed killers for railway ballast treatment, so it was necessary to start from scratch. We proceeded however, with the generally accepted practice of laboratory research, which included greenhouse small plot tests, although without expecting that the results of such tests would apply on actual railway treatment. It was just a case of deciding upon a starting point and using the process of elimination.

It was learned from the literature search that most experimenters use square rod plots for field testing and, as a rule, on level ground off track, so we determined at the outset to make all field tests "on-track" comparable to actual conditions under which large-scale railroad applications are made. Obviously, there is considerable difference between off-track and "on-track" testing, because with a ballast section built-up for the particular purpose of providing drainage, chemicals are more easily leached from the ballast and sub-ballast than would be expected when chemicals are applied on level ground. It is also obvious that testing in semitropical locations during fall and winter months, nearing or at the end of a growing cycle, cannot be considered the same as testing for use of chemicals in other than semitropical locations during the vigorous growing season. It was decided, therefore, to do all field testing during the normal growing season and, to include all factors which might influence results, we prepared to test at six different locations throughout the Southeast—Florida, Georgia, Alabama, Tennessee, South Carolina and Virginia. In place of using the usual square rod test plots off-track, our procedure called for each test to be ¼ mile long and 20 ft. wide "on-track," with ample space between plots to act as check plots to permit more accurate observation of results.

Each test was applied with a small-scale spray equipment mounted on a section push car and propelled by a motor car. A constant speed was maintained with the aid of a speedometer attached to the motor car, and 100 gal. of solution was applied on each test plot. A total of 454 of these ¼-mile "on-track" test applications were made during the three series of field testing—late spring, early summer and late summer—and the program included the testing of 30 recognized weed killers or combinations. Observations of results were made one week and one month following each application of all three series, which means that each location was visited nine times during the five months April to September.

In evaluating weed killers, it is well to bear in mind that it is just as important to determine those that give negative results as it is to know those that provide positive results. This made it necessary, in starting our research program, to try some chemicals and combinations that might otherwise have been disregarded completely without testing.

In this presentation I will not attempt to do other than to give conclusions as to positive results.

Of the 30 weed killers and combinations tested during 1949, only seven show real merit, within a cost range, for ballast treatment in the Southeast, namely:

Sodium chlorate-calcium chloride weed killer
Sodium trichloroacetate-formula 40 (2, 4–D amine)
Sodium chlorate-sodium trichloroacetate
Sodium trichloroacetate-pentachlorophenol

We have deliberately left the way open on this because there is some element of the angle of the wave train which affects the coefficient. We hope that subsequent studies and observations of actual results may make it possible for us to change the 1.4 to some constant, and to give you a table of constants to use in connection with the angle of the wave train lengths with the face of the embankment.

Again, we would like very much to have information from all of you who have had experience through reservoir areas, as to the question of wave lengths, and as to how your experience checks with the formula we have presented to you as information this year. There is no way to be sure the formula is right except by checking it in actual cases.

You will probably find, as we did, there is no greater exaggeration in the world than exists with respect to the height of waves. You come in when you have been at sea and talk about 50 or 60-ft. waves. At Lake Texoma, there is a ten-mile fetch where the waves strike against the embankment of our railroad. We have variations in wave heights there from six to ten feet. Now, that is a wide variation. When the United States Government gets its wave gages in operation, measuring the velocity of the water and wind and the amount of upthrust of the waves, we should have something definite to go by.

Vice-President Loeffler: They say that time waits for no man. We have arrived at high noon. We must now adjourn to attend the Annual Luncheon.

(The session was adjourned at 12:00 noon)

[The Annual Luncheon was held in the Grand Ballroom, Wednesday, March 15, with 1013 members and guests in attendance. The feature address was presented by W. G. Vollmer, president of the Texas & Pacific—Vice-President H. S. Loeffler presiding. For the text of Mr. Vollmer's address, see page 789.]

(The afternoon session was convened at 2:30 p. m., with Vice-President H. S. Loeffler in the chair.)

Vice-President Loeffler: The meeting will please come to order for the afternoon session. The Committee on Roadway and Ballast will proceed with its report.

Chairman Legro: Committee 1, has no formal presentation to make on its Assignment on Chemical Eradication of Vegetation. However, the subcommittee has been very energetic under the leadership of Mr. Crosland. The possibilities of determining through research the most economical and effective means of weed eradication, both completely and selectively, led this committee to recommend an AAR appropriation for this work last year. The necessity for temporary curtailment of the AREA program for research prevented the start of a full-scale study of this subject this year.

However, there is being conducted an independent investigation of weed killers so closely related in some of its aspects to our own contemplated program that our committee deemed it of interest to this convention. This investigation is a cooperative one, involving, as cooperators, the Southern Railway, the Seaboard Air Line, Virginia Polytechnic Institute, and the R. H. Bogle Company.

Mr. Jack Taylor has received his Master's Degree at Virginia Polytechnic Institute and his thesis for the degree was based on the research work conducted by the R. H Bogle Company on these railroads. Mr. Taylor has prepared an industrial report from his thesis, and he will now give us a brief talk abstracted from that report. This talk is illustrated with slides.

Discussion on Yards and Terminals

(For Report, see pp. 178–198)

Chairman W. H. Giles (Missouri Pacific Railroad) introduced, in turn, the several subcommittee chairmen, who presented their reports.

Assignment 2—Classification Yards, Collaborating with Committee 16. In the absence of Subcommittee Chairman B. Laubenfels (Chicago, Burlington & Quincy) the report was presented by title only by F. E. Austerman (Chicago Union Station Company).

Assignment 4—Bibliography on Subjects Pertaining to Yards and Terminals, was pesented by Professor W. C. Sadler (University of Michigan).

Professor Sadler: The peculiarities of work on a bibliography tend over the years to cause the bibliography to expand. Thus, we found ourselves confronted this year with a pattern whereby much collateral material was included in the direct report. Therefore the entire field was restudied, with the result that the report this year is on a definitely more restricted basis than in previous years. The committee is of the opinion that space and general considerations warrant this procedure.

(President F. S. Schwinn resumed the chair)

Assignment 6—Facilities for Mechanical Handling of L.C.L. Freight, Collaborating with Committee 6—Buildings. Subcommittee Chairman W. O. Boessneck (Erie Railroad) presented a brief abstract of the report.

Assignment 7—Relative Advantages and Physical Factors to be Considered in the Design and Selection of Flat, Gravity or Hump Yards for Handling Various Volumes and Kinds of Traffic. A brief outline of the contents of the report was presented by W. H. Goold (New York Central).

Assignment 8—Design of Track Layout and Gradients in Connection with Scales Located on the Hump of a Classification Yard. A brief synopsis of the report was presented by D. C. Hastings (Richmond, Fredericksburg & Potomac), who said: This assignment will be continued next year from this point, and an attempt will be made to present some typical installations and to show the actual gradients and track layouts to use.

Assignment 10—Recent Developments in Under-Car Inspection of Freight Cars, was reviewed briefly by A. S. Biermann (Terminal Railroad Association of St. Louis), subcommittee chairman.

Chairman Giles: I want to call your attention to the large committee that we have here, although we are six short of our total. We would like to have applications for committee membership from others interested in terminals, particularly those with operating experience. Write to our secretary if you are interested in joining this committee.

Incidentally, in studying our committee personnel here today, I decided to find out how many years of membership are represented. I found there are a total of 702 years of AREA membership represented on this committee, the members of which have an average membership age of 13 years. Each of five on the committee has served this Association for more than 30 years.

President Schwinn: Mr. Giles, your committee has rendered an excellent report, not only at this meeting, but in previous years. We hear a great deal of criticism of the yards and terminals on American railroads, much of which would not be if we heeded all of the recommendations of your committee. Thank you, Mr. Giles. The committee is excused.

Sodium arsenite–sodium pentachlorophenate
Sodium arensite–oil 214–A
Oil 214–A alone

Soil conditions represent one of the factors which affect the action of weed killers. It so happened there was little difference at the six test locations. Soil type varied from sandy at Palmetto and Valdosta, Ga., to sandy clay loam at the other locations. Organic matter content ranged from 1.0 to 7.0 percent—pH values ranged from 4.0 to 7.0. Thus, no effect on the action of the herbicides tested could be determined from these small differences in soil conditions.

The determination of the effect of weather conditions on the action of the herbicides tested led to the following conclusions:

1. That in all cases better results were obtained when there was sufficient rainfall to produce active growth of the vegetation.
2. That the contact herbicides gave better results when the weather became dry following application.
3. That a hard dashing rainfall of one or more inches was necessary to reduce the action of the herbicides materially.

The determination of the most effective time for application during the growing season led to the following conclusions:

1. That, with similar rainfall conditions, results obtained with sodium chlorate–calcium chloride weed killer and sodium trichloroacetate–formula 40 were not affected by early or late season application.
2. That the sodium chlorate–sodium trichloroacetate combination gave the same results when applied between June 5 and September 4, 1949.

Analysis of results of all formulations tested led to the following conclusion:

> That the most economical chemical herbicide formulation for Johnson grass, Bermuda grass and weeds growing together, was the sodium chlorate–sodium trichloroacetate combination, two pounds of the former to one pound of the latter (60 percent equivalent).

Our research program so far has been confined to the Southeast, and while the conclusions reached could very well apply to other parts of the country where Bermuda and Johnson grass predominate, we are in no position even to imply that the same conclusions would be applicable where different types of perennial weeds and grasses grow.

Furthermore, we consider last year's testing was only a start, and it is our intention to continue this research program in the hope of making a real contribution toward chemical track weeding.

Vice-President Loeffler: Mr. Taylor, the Association thanks you very much for your interesting presentation. We hope to hear from you again at some future date.

Chairman Legro: Mr. Chairman, this concludes the report of Committee 1.

Vice-President Loeffler: Mr. Legro, we thank you for a very interesting report. Your committee is dismissed with the thanks of the Association.

some instances had become so severe that Bessemer rail was no longer adequate. In 1909 the American Society for Testing Materials published two standard specifications for steel rails, one for Bessemer rails and the other for open-hearth rails. These specifications covered rail sections that ranged from 50 lb. per yard to 100 lb.

From then on, open-hearth rails rapidly began to supersede Bessemer steel rails. In the ensuing years the service requirements outgrew the capacity of the 100-lb. sections, and heavier rail sections weighing up to 155 lb. per yard are now in service.

The close cooperation between the technical personnel of the railroads and that of the steel industry contributed greatly to the development and improvement of the types and qualities of steel for rails and other equipment needed to keep pace with the progress in railroad transportation since the beginning of the century. This cooperation between railroad men and those who make steel was implemented by joint committees within the framework of the ASTM, by the cooperation of your technical committees and those of the Association of American Railroads with the technical committees of the steel industry, and also by important contributions from individuals of both of our industries.

Throughout this period impressive advances in quality resulted from the application of scientific methods and controls in steel manufacture and from improved methods of inspection. Important improvements in the means and methods of inspection, both before and during the service life of steel components, have added to safety.

Transverse Fissures

The conditions which made it necessary to produce heavier rail sections of harder and stronger steel introduced features which had not been experienced before, and which for some time were difficult to understand. One of the serious problems was that of transverse fissures which developed in rails during service. About 1920 this problem had become one of extreme importance, both from the standpoint of maintenance and operation, and of public safety. An increasing number of rail failures was ascribed to such fissures. Improved methods of inspection in the railroad right-of-way (notably the development of the detector car for locating fissures before they had spread to final fracture), distinctly reduced the probability of ultimate rail failure. But this by no means entirely eliminated such danger, and the problem of preventing the fissures continued to be seriously important.

It became apparent that a rail not susceptible to this type of failure was the only solution, and intensive research work was inaugurated toward this end. This research began to produce results shortly before 1930. The patent literature of the period 1928 through 1942 marks the progress of the research that resulted in present-day procedures for the control cooling of rails.

On January 1, 1931, there was formally inaugurated a joint investigation of internal fissures in railroad rails. That investigation was organized under the auspices of the Rail Manufacturers Technical Committee (now the American Iron and Steel Institute Technical Committee on Rails and Joint Bars) and the American Railway Association (now the Association of American Railroads), the latter acting through the American Railway Engineering Association. The Engineering Experiment Station of the University of Illinois was selected for the purpose of carrying on an active program of research. The agreement for carrying on this work was completed March 17, 1931, and work was initiated under the direction of Professor H. F. Moore. An advisory committee composed of members of the Rail Manufacturers Technical Committee and the Association of American Railroads was appointed to keep in touch with the progress of the investigation.

Discussion on Rail

(For Report, see pp. 541–647)

Chairman Ray McBrian (Denver & Rio Grande Western): Your committee has reports on 11 subjects, which are found in detail on pages 541 to 647, inclusive. However, we have decided to deviate from past practice and not present any of these reports, but rather present addresses on four subjects which are vital to the problems studied by the Rail committee. I would like to ask that our 11 assignment reports be accepted as progress reports, inasmuch as they involve no changes in the Manual.

We would like to present as our first speaker, Mr. L. H. Winkler, metallurgical engineer of the Bethlehem Steel Company, who is also chairman of the Joint Contact Committee of the American Iron and Steel Institute and the AREA Rail committee.

The Problem of the Steel Rail

By L. H. Winkler

Metallurgical Engineer, Bethlehem Steel Company

Although time will not have passed the half-way mark of the twentieth century until January 1, 1951, America can look with pride upon the last 50 years as a half-century of technological and scientific progress. No one industry can be named as the principal contributor to that progress, but our development could not have been as rapid without the network of railroad transportation systems that has served as the chief integrating force of our national economy. Moreover, if we do not jealously guard the strength and efficiency of our railroads during the years that lie ahead, this country cannot hope to retain its leadership and influence in making the world better for all human beings.

This half-century of progress by the railroad industry, except for the period of Governmental operations during World War I, went forward at a steadily increasing pace. That this was accomplished in spite of restrictive and discriminatory regulations is impressive evidence of the superiority of our time-honored system of free private enterprise over any of the other systems that some promote. But continued progress can only be assured by a wise Governmental attitude toward conscientious and able private management, and by loyal cooperation from those who serve the railroads and those served by them.

Many Contributions Through Cooperation

It may be helpful to review some of the contributions resulting from cooperation between the engineers of the steel industry and of the railroad industry during the last 50 years, and to emphasize some of the items of unfinished business for the years ahead.

The rapid development of railroads, which began a few years prior to 1900, was made possible by the Bessemer steel rail, which superseded the old wrought iron rail. The speed of railroad trains had increased considerably and the wheel load of cars had increased at least 75 percent. The wheel loads of locomotives had increased probably over 100 percent and the volume of traffic by at least 300 percent. All of this was made possible by the Bessemer rail.

The peak of Bessemer rail production and its predominance, from a tonnage standpoint, in relation to the open-hearth process was reached in 1906. Standard specifications for steel rails up to 1908 were based on Bessemer steel, but by this time the service in

It appears reasonable at the moment to associate shelling with the flow of metal, in and near the surface of the rail head, resulting from cold work of the rolling loads imposed upon the rail. The assumption is that this type of failure is the result of shear or slip when the forces have exceeded the elastic limit of the steel or its capacity to endure further localized distortion. This hypothesis seems to explain the gage corner type of shelling, but the progressive failures which are located deeper within the head of the rail, and generally composed of both horizontal and vertical components, are not as easily understood.

Study Shelling With Rolling-Load Machine

A great deal of work has already been done at the University of Illinois by subjecting specimens to tests by a rolling-load machine. This test is designed to simulate service action under accelerated conditions and is conducted under a wheel load of 50,000 lb. Such tests have been made on as-rolled specimens and heat-treated specimens of standard rail steel composition, intermediate manganese rail steel, and a large number of alloy grades, including 3 percent chromium steel.

It is, of course, not expected that laboratory tests will always provide us with a final answer to problems such as these. Such tests, however, are made in the search for guidance. For one thing, these rolling-load tests appear to show that steel of higher Brinell hardness than standard rail steel also withstands a greater number of cycles before breaking down than the as-rolled standard rail specimens. The same is true of heat-treated specimens of standard carbon steel rails.

Adopting this lead, experimental track has been laid in service composed of rails made of 3 percent chromium steel, rails of standard analysis with molybdenum added, and also carbon steel rails of higher than normal carbon content; all in the as-rolled condition. Heat-treated rails of standard composition have also been placed in service. It is too early to evaluate completely the performance of all of these test installations.

We know that the manufacture of rails from 3 percent chrome steel and the heat treatment of standard carbon steel rails introduce major difficulties; thus, further intensive efforts are justified to develop a steel which, in the as-rolled condition, will have the properties which appear desirable. Therefore, research work to this end is being continued by the manufacturers, and is receiving active attention from your Joint Committee. Laboratory pilot heats of steel are being made. When a composition is found that gives promise of a hardness in excess of 300 Brinell in the as-rolled rail section, small production lots will be tried. This problem includes steels of chrome molybdenum, chrome molybdenum vanadium, and chrome vanadium types. It is thus hoped that rails from steel of such compositions may soon be placed in test service.

More Field Studies Needed

While the research we have discussed may develop important information, many of us believe that the solution of the shelly rail problem may not be found by that approach alone. We feel the need of more detailed data obtainable only through field studies made by railroad men. In what locations and under what operating conditions does serious shelling develop? So far most of it appears to be encountered on curves on the high or outside rail, but it also occurs in tangent track. Where in the length of the individual rail are progressive failures most likely to appear? Do they appear more frequently on the entering end of a curve or on the leaving end? Under what conditions do they appear in tangent track?

We must by all means continue our metallurgical studies, but we should not lose sight of the possibility that the best final answer and the best engineering economics

A smaller group, composed of engineers from both our societies, was selected from the advisory committee to act for and represent the larger committee in its relationship with the University. This smaller committee is known as your Joint Contact Committee.

Solution Found in Control Cooling

The advisory committee and the University of Illinois studied the control cooling procedures inaugurated by the rail manufacturers and endorsed certain methods as a corrective means toward obviating this type of rail failure. One result of this cooperative work at the University of Illinois has been the outline of recommended practice for control cooling, as later adopted by the AREA.

Thus the solution of the problem of transverse fissures was found in the control cooling of rails at the mills. The rapid adoption of control-cooled rails on this continent is indicated by the fact that the total tonnage of control-cooled rails purchased up to June 30, 1942, by the principal railroad systems in the United States amounted to 4,861,295 tons. Current rail statistics carefully gathered by the AAR clearly show that control-cooled rails are not subject to failure due to transverse fissures. Since a large tonnage of these rails has been in service for a number of years we can now consider this type of failure a thing of the past, and regard that problem as an item of finished business.

Shelling of Rails

On the list of unfinished business is the problem of rail shelling and the associated phenomenon of detail or progressive failure. Immediately following the solution of transverse fissures, this became of so much concern to our Joint AREA–AISI Contact Committee that the scope of our research program at the University of Illinois was extended into that field. A supplementary research program was also started at Battelle Memorial Institue in 1946, and now research is being pursued actively at both institutions under the auspices of our two cooperating societies.

Before progress can be made in the solution of any problem such as this, one must develop information as to the contributory causes and the manner in which the failure develops. The success or failure of corrective measures depends, of course, upon the accuracy of our diagnosis. We are still engrossed in the search for comprehensive information.

A study of numerous specimens of rails removed from service was made at Battelle. Some of these specimens were taken from rails that had been removed from track because of progressive types of failure. Others, for comparative study, were taken from companion rails, which did not exhibit such defects, removed from the same general track locations in which the defective rails were found. This investigation failed to connect those detail failures with any unusual or abnormal quality of the steel. No evidence was found to indicate that non-metallic inclusions in the steel or its mechanical properties were responsible for the development of the progressive failures.

Work in the field of stress analysis has yielded important results in the solution of many types of machinery and equipment failures that have heretofore been baffling to engineers and metallurgists. Your committee considered it advisable to investigate the possibilities of such an approach in the study of rails. Therefore, after the first assignment to the Battelle Memorial Institute had been completed, that institution was given a project to determine whether a reliable method for the analysis of stresses within a rail structure can be developed. If this study produces promising results, further research into that field of stress analysis may be undertaken.

greater speed. But later the pioneering spirit and drive of railroad motive power engineers resulted in the building of tremendous steam locomotives, some of which weigh upwards of 600 tons, designed for speeds up to 80 mph. and able to produce continuous maximum power output at speeds up to 70 mph. This has made possible the operation of coal trains of 160 to 175 cars carrying total loads of 14,000 to 15,000 tons gross, up and down substantial grades. We have freight trains of as much as 9000 tons scheduled to a speed of 50 mph. that frequently reach actual speeds of 60 mph. We also have trains of 14,000 tons gross that are scheduled at 45 mph. and actually reach speeds of 55 to 60 mph.

Tremendous Service Requirements of Rail

In our consideration of the work of wheels and rails, we generally think in terms of wheel loads. Perhaps we should give more thought to the tremendous energy factors which present train loads and speeds entail. Granted, this latter is more difficult to evaluate than wheel loads, but the energy that is transmitted to the rail, plus the great increase in impact loads incident to high speed, must add tremendously to normal static loads.

On old style prewar passenger cars the total weight ran as high as 190,000 lb., carried on two six-wheel trucks; equivalent to 15,800 lb. per wheel. Those cars seldom operated at over 60 mph. and the energy to be dissipated at each wheel in stopping from that speed was 1,900,000 ft.-lb. In one of the most recently built groups of so-called "light weight" type for trans-continental service, the actual car weights run from 152,850 lb. to 171,620 lb., with individual wheel loads varying from 19,100 lb. to 21,400 lb. These trains operate at much higher speeds, often with much mileage in excess of 90 mph. In stopping a car with 21,400-lb. wheel load from 90 mph. the energy dissipation is 5,800,000 ft.-lb. In the case of a modern diesel locomotive, which has an average load of 28,000 lb. per wheel, a stop from 90 mph. involves the dissipation of 7,600,000 ft.-lb. of energy per wheel.

The first heavy diesel freight locomotive was bought by the Santa Fe in 1941. The four-unit locomotive weighs over 460 tons, develops a starting effort of 110 tons, and has been used in hauling 60 cars of 3150 tons gross of general freight at passenger train speeds.

It is true that these figures are more significant and tremendously important to the wheel. Unless the greatest care is observed in the proper operation of the braking system and in the proper maintenance of the entire brake rigging, serious wheel troubles will be experienced. But the foregoing examples of gross loads, speeds and energy should give us some idea of the job that the rail, and indeed the whole track structure, must perform in normal free running. Moreover, in the retardation and acceleration of trains and in the change of direction at curves, the rail and track must support forces that are truly enormous.

We have seen many improvements in the design of the components of locomotives and rolling stock, such as roller bearings. These have all been with a view toward improving running gear that is above the rail-head surface. It is not unreasonable to expect that future efforts directed toward improvement in the design and maintenance of rolling stock and track will be focused on items that will help the rail to give better service. A number of little helps in that direction may prove of great importance. More field data, as before mentioned, are needed to direct the way.

might result from an approach involving improvements in mechanical design as well as in metallurgy. The more simple problem of gears was not completely solved by metallurgy, and the answer was not found until tooth design was also improved. We sincerely hope that a searching field study program may soon be inaugurated to supplement the metallurgical research work now in progress.

That the railroads are alert to the close relationship between the track structure, wheel loads, train speeds and rolling stock is evidenced by the research work in progress by individual railroads and by the research department of the AAR. In that research, special test tracks and sensitive instruments are employed for the measurement of forces and stresses under actual operating conditions. Committees of your association are giving much time to such studies. All of this is most important, but it is believed that special field studies, directed specifically at the problem of rail shelling, are needed to supplement our present research into the causes and correction of such failures. It seems reasonable to expect that a solution of this problem can be expedited if some relief (regardless of how small it may first appear), from the tremendous punishment the rail receives can be brought about by improvements in the design and maintenance of our rolling stock and the operation of trains. In addition to supplying other needed data, these field studies might suggest some relief of this kind.

Severity of Present-Day Service

We spoke of the great advances in railroading that the early years of this century saw and the part that rails were called upon to assume in that remarkable performance. Let's look at the record as it appears today and think about what it might mean to the steel rail.

About 10 years ago we had a few passenger train miles scheduled at 60 mph. and over, with fewer train miles scheduled to operate at 70 mph. or better. Today we have over 20 trains, operating daily, that are scheduled at speeds of 75 mph. and over for significant mileages.[1] The streamliners account for this increase in the speeds of passenger trains, but more was involved to accomplish this fast comfortable travel than streamlining or diesel power. Satisfactory and safe operation was made possible by profound improvements in the right-of-way, by realinement of tracks, signaling improvements, reduction in grades, the use of heavier rail, the easing of curves and other important items with which you are better acquainted than we manufacturers.

While such passenger train service has tremendous public appeal, freight transportation is the bread and butter of our domestic economy and of utmost importance to our national defense. Heavy freight, such as ore, coal, oil, steel and building materials, is extremely essential to our industrial supremacy. In the 10-year period 1935 to 1945, the net ton-miles per mile of road per day increased to 2.4 times what it was in 1935.[2] The freight train has developed from a slow and plodding servant to a point where passenger trains must look to their laurels. High-speed freight trains are definitely threatening the speed record of fast passenger service. A justifiable pride has led the railroads to christen their fast general merchandise trains with appropriate names, a distinction that once belonged only to the elite passenger train.

The healthy competition between individual railroad systems and the growing competitive threats of other means of haulage have stimulated the development of motive power. The traffic requirements of World War I probably brought the first great demand for freight motive power capable of handling heavier trains loads at

[1] "The Fastest Trains" by H. E. Lobdell, Technology Review, January 1950.
[2] Interstate Commerce Commission, Fifty-ninth Annual Report on the Statistics of Railways in the United States for the Year Ended December 31, 1945, p. 53.

standard rail suitable for all purposes . . . The adoption of a standard rail would afford great facilities to the manufacturer by diminishing his stock of rolls and allowing him to manufacture in slack times, and to supply any sudden demands from stock. It would lessen the cost of production and afford the general advantages to the consumer and producer, which have hitherto resulted in all cases from the adoption of universal and standard measures.

Benefits for All in Greater Standardization

It may not be practical to accomplish the standardization of the railroad rail section to the extent visioned by Bessemer, but when we see the great number of rail sections at present produced, it must be evident that much can be accomplished that in the end will react to the benefit of all of us. The current list of rail sections produced by American rail mills include: two 80-lb. sections, two 85-lb. sections, two 90-lb. sections, five 100-lb. sections, five sections ranging from 101 to 121 lb., and seven sections weighing over 121 lb., per yard; a total of 23 current sections.

We are far from standardization in splice bar section designs, length of bar and spacing of bolt holes. The number of different rail drilling designs in demand for the 131-lb. AREA rail section alone is astonishing.

It is recognized that simplification and standardization in the few cases mentioned above will be very difficult, but it is believed possible to accomplish gradual progress that will finally pay off in overall economy. Moreover, some accomplishment of this nature will stimulate further progress in the standardization of other steel commodities produced for our railroads.

In bringing this paper to a close may I quote from Glanvill who, in 1650, wrote:

> "Iron seems a simple metal. But in its very nature are many mysteries, and men who bend to them their minds shall in arriving days gather therefrom great profit, not to themselves alone but to all mankind."

President Schwinn: That was a fine paper, Mr. Winkler.

Chairman McBrian: In this problem of the steel rail, the Rail committee feels that from time to time it is necessary to review the various types of rail failures, so that when reports are received the proper classifications can be made. To that end we have asked Mr. R. E. Cramer of the University of Illinois to give a short talk for the purpose of refreshing your minds on rail failures and their causes. Mr. Cramer.

(Mr. Cramer presented a brief review of the current work of the committee in the study of the causes of rail failures, illustrated with lantern slides.)

Chairman McBrian: Mr. Winkler mentioned in his address the important problem of shelling rail and detailed fractures, which is being studied by the Rail committee and the Joint Contact Committee. To refresh your memories on this, we have asked Mr. G. K. Manning of Battelle Memorial Institute to give us a brief review of the studies that the Institute is now making.

(Mr. Manning described briefly the studies on rail fractures being carried on at Battelle Institute.)

Chairman McBride: I would like to urge all those who are especially interested in rails to look over the display board here carefully. It is a collection of failure specimens made by Battelle. After you see this display, I am sure you will agree with what

Standardization and Simplification

It seems appropriate that this paper should include recommendations for more effective efforts toward standardization and simplification of the steel products in which this audience is vitally interested. If in North America we did not have the standard track gage and the essential standardization of rolling stock, railroad transportation, as we know it, would be impossible. Standardization has been one of the important interests of the AAR, and it is evident that the technical committees of that association consider there is still much to be accomplished.

The relationship between standardization and simplification has been described by the National Bureau of Standards[3] as follows:

> The term simplification, when used in the sense of eliminating unnecessary variety, is sometimes confused with technical standardization processes. Technical standardization is creative; its function is to determine and establish in use the best design, quality and method or process for performing a desired function. The simplification process, on the other hand, is commercial and selective; its function is to determine which sizes or items of a product are most important, and to concentrate production on them whenever possible. Simplification may be applied to articles already technically standardized as to design or size, or it may be applied as a step preliminary to standardization, thereby clearing the way and reducing the number of items to be dealt with.

The benefits to be derived by everyone from such a program of simplification are set forth in the same document as follows:

To the Producer and Manufacturer

1. Less capital tied up in slow-moving stocks.
2. More economical manufacture due to simplified inspection requirements, longer runs with fewer changes, less idle equipment, less stock to handle, etc.
3. More permanent employment as contrasted with seasonal employment.
4. Larger units of production and less special machinery.
5. More prompt delivery.
6. Less chance of error in shipment.
7. Less obsolete material and machinery.

To the Consumer

1. Better values than otherwise possible.
2. Better service in delivery and repairs.
3. Better quality of product.

The necessity for standardization in the steel industry became evident long before the present century, and engineers and technologists took action as opportunities occurred. In an issue of the Bulletin of the American Iron and Steel Association, dated April 19, 1871, we find an extract from an address before the Iron and Steel Institute of England by Sir. Henry Bessemer, the president, from which the following is quoted relative to the manufacture of rails:

> The work which a rail has to perform is so perfectly simple, and so clearly defined, that there cannot at the present day be any difficulty in establishing a

[3] "Simplified Practice, Its Purposes and Application." Letter Circular L. C.–590, U. S. Department of Commerce, National Bureau of Standards, April 15, 1940.

did some excellent work. It is recognized that what we need now, more than anything else, is actual data on the relative life, and on the relative labor costs, of rails for different traffic conditions.

Mr. C. M. Chumley, who is now chairman of the Rail subcommittee on this assignment, has been quite active in the work, and that subcommittee has presented reports the last three years which contain some very helpful information. The report this year, in particular, includes studies on the Pennsylvania Railroad and the Illinois Central Railroad, which contain the kind of factual data we need in order to arrive at a satisfactory conclusion of this subject.

I would like to make some personal observations on some things in connection with this problem because of the interest I have had in the subject. First, on the life of rail. We ordinarily think of rail life in terms of carrying a certain amount of traffic. That isn't necessarily true, because it is quite certain, I think, on a railroad having a relatively light traffic capacity of 5 million gross tons annually, you can't put in 155-lb. rail and have it carry 1 billion gross tons of traffic. That would represent a life of something like 200 years. I don't think any of us would think it would last that long. However, on the other hand the 155-lb. section will carry 1 billion gross tons of traffic under certain very heavy traffic conditions, such as the Pennsylvania Railroad has. We must, therefore, eventually arrive at some kind of a formula, or diagram, that will take into account in the life of the rail, the traffic density carried on the line.

There are certain other things that have a bearing on the life of a rail, such as rail failures, possible damage to rail by driver burns, and matters of that kind. But, I believe that we are now getting pretty close to the point where the experienced railway men on the committee can put their judgment together and set up some pretty good recommendations as to what we can consider the relative life of the different rail sections under different traffic conditions.

The track labor requirements for different types of rail are another subject on which we need more data from actual railroad experience. It will certainly be very helpful if some of the railroads that have different rail sections in use can provide the subcommittee with this data.

There are two other items that are affected by size of rail, such as tie life and maintenance of equipment. In my opinion, the weight of rail will have an important influence on maintenance of equipment cost, especially with the high operating speeds of today. However, this is a very difficult benefit of heavy rail to evaluate accurately.

Two studies published in the subcommittee's report this year show some very attractive economies from the use of the heavier rail sections on what I would consider heavy-traffic density lines—around 25 to 30 million gross tons a year. In my opinion, many of the railroads in this country should be giving serious consideration to the use of 155-lb. rail. I am not even sure that we shouldn't be thinking a little about the design of even heavier sections in view of the tremendous increase that has taken place in our track labor costs.

Chairman McBrian: This completes the presentation of our committee.

President Schwinn: We wish to thank these four speakers for their very splendid talks. Mr. McBrian, you and your committee are to be highly commended for the rather unique presentation which you have given us this afternoon on the general subject of rail. You are excused with the thanks of the Association.

Mr. Manning and the others have said about the complexity of the detailed fracture problem.

In our work during the past year, especially with the rapid dieselization that is coming on, the question has been frequently raised as to the economic size of rail. No one is better prepared to discuss this subject than Mr. Gerald Magee, research engineer, Engineering Division, AAR, who will do so at this time.

The Economic Size of Rail

By Gerald M. Magee

Research Engineer, Engineering Division, AAR

I was asked to talk on this subject because it is one that has been of very close personal interest to me. A study of the economical weight of rail was one of my first railroad research jobs.

The Kansas City Southern, started using 85-lb. rail about 1905. In 1924 it decided to go to 100-lb. Two years later, Mr. L. F. Loree, who was chairman of the board of that road, was asked to give his approval to increasing the weight of the rail to 110 lb. He told Mr. C. E. Johnston, who was then president, and Mr. A. N. Reece, the chief engineer, that he thought we shouldn't just increase the weight of rail every two or three years, but should make a thorough engineering study of the properties that were required in a rail to handle the conditions on our road most advantageously and economically.

I was two years out of college at that time, a draftsman in Mr. Reece's office, and he assigned me to make the study. Mr. Reece told me later that Mr. Loree had suggested to him to pick out some young fellow out of school, who didn't know very much and put him on the job. Well, anyway, I got the job and I worked on it for about two years. While it isn't one of those problems that can be worked out by any mathematical proof, so there is no element of uncertainty in the results, nevertheless, I was convinced when I finished the work, that by careful study of the various factors involved, one could come to a rather intelligent decision on the weight of rail that should be used on our property. The conclusion we came to in this particular study was to recommend 127-lb. rail for use on the Kansas City Southern, as best suited, of the rail sections then available, to the conditions prevailing on the railroad.

At that time, the traffic density on the Kansas City Southern was only about 6,000,000 gross tons per year. This represented a rather radical departure, for a light-traffic line to use that heavy a rail section. But, I don't think anyone on the railroad has regretted the decision, and during the war, with labor conditions the way they were, that rail section was certainly a great deal of help.

In my opinion, the most constructive work from the research standpoint that came out of that particular investigation was knowledge of the effect of different weights of rail on train resistance. I believe that the data now appearing in the proceedings, under the Committee on Economics of Railway Operation, are a very dependable guide, and can be considered as conclusive, on the relative train resistance over the different rail sections. That part of our study of heavier rail, I think, we can pretty well lay aside.

Since the study on the K. C. S., the Rail committee has continued its studies on the economical size of rail. Mr. Farrin was chairman of the committee for many years and

His experiments, conducted at the age of 23, revealed that beyond the highly brittle compositions of 4–7 percent Mn, there existed a region beginning at about 10 percent Mn and extending to approximately 20 percent Mn, within which the steels showed unusual combinations of strength and ductility. Such properties were obtained by what was then called "water toughening;" namely, the same high temperature heat treatment followed by water quenching that is used today.

General Properties

The outstanding characteristics of cast manganese steel depend chiefly on an unusual feature of its structure. The high manganese content contributes a fortunate form of low temperature stability to the phase existing otherwise only at high temperatures, which is known as austenite. Instead of transforming on quenching, as with tool steels, the austenite in this case is retained by a water quench and then exists at room temperature with relative stability. The normal structure is, therefore, a nonmagnetic, soft (180–200 BHN), ductile, and tough austenite which retains all the carbon of the steel in solid solution.

A recognized lack of complete stability is, however, a beneficial factor within limits, in that cold work induces a partial transformation of the austenite in a sufficiently homogeneous fashion as to increase the hardness and the proportional limit without spoiling the ductility. It is this ability to work harden which confers the high degree of toughness which this steel possesses. This is, in general, measured by the area under the true stress-strain curve of the tensile test, and on this basis is unsurpassed.

The chemical composition can be adjusted within flexible limits without impairment of mechanical properties. A typical analysis will contain 1.15 percent C, 12.8 percent Mn and 0.50 percent Si.

In the as-cast state this alloy is relatively weak and brittle. This is because the austenite during a slow cool breaks down locally, transforming at the grain boundaries to produce networks of bainite, pearlite and/or carbides. All castings are, therefore, heat treated as soon as possible after removal from the molds. This normally consists of soaking at a temperature usually above 1800 deg. F. for an hour or more per inch of metal section and then quenching in water.

As heat treated, the mechanical properties depend to some degree upon the grain size of the metal. Unlike carbon and alloy steels which are employed as-quenched and tempered, the grain size of manganese steel does not respond readily to heat treatment but is chiefly determined by the temperature of the molten metal at the time the casting was poured. If a high pouring temperature is used, freezing takes place slowly and large grains form. With cold pouring, freezing proceeds rapidly and a fine-grained structure results. This behavior affects strength and ductility in a fashion which will be discussed in later paragraphs.

Standard manganese steel in general, however, will possess the following representative properties:

Yield strength—45,000–55,000 psi. (0.2 percent permanent set)
Tensile strength—120,000 psi. (avg.)
Elongation—40 percent (avg.)
Reduction of area—35 percent (avg.)
Young's modulus—29,000,000 psi.

These values apply strictly to the as-heat treated state. Tempering will induce damaging transformation with structures quite similar to the as-cast condition.

Discussion on Track

(For Report, see pp. 649–706)

Chairman E. W. Caruthers (Pennsylvania Railroad, retired), introduced, in turn, the various subcommittee chairmen, who presented the committee's reports.

Assignment 3—Track Tools, was reported on briefly by Subcommittee Chairman C. E. R. Haight (Delaware & Hudson), who moved the adoption of plans 11–50, 20–50 and 20–A–50, as presented in the report.

(The motion was seconded, put to a vote and carried.)

Assignment 4—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, A. B. Hillman (Chicago & Western Indiana), subcommittee chairman.

Mr. Hillman: Your committee has prepared revised plans of spring frogs to improve the vertical stability of the spring wing rail, and has also prepared revised plans of crossings within the range of angles from 14 deg. 15 min. to 8 deg. 10 min., to provide better guarding for the center frogs.

The plans that we recommend for adoption, to be published in the Portfolio of Trackwork Plans, are listed on pages 652 and 653. The adoption of these plans necessarily call for the withdrawal of some present plans. These are listed on page 653. I move the adoption of the plans listed as recommended practice for publication in the Portfolio of Trackwork Plans, and the withdrawal of the present plans listed.

(The motion was seconded, put to a vote and carried.)

Chairman Caruthers: A great deal of the work of the Track committee has been under the supervision of Mr. G. M. Magee, research engineer, Engineering Division, AAR, who has very kindly consented to give us a brief resumé of the work that has been covered this year by his organization.

(Mr. Magee obliged, referring concisely in his remarks to the various studies and installations being carried out by the research staff for the committee, all of which are reported on in considerable detail in the committee's report, pages 649–706, inclusive.)

Chairman Caruthers: We are fortunate in having with us today, a scientist whom I am going to ask Mr. Huber to introduce.

A. F. Huber (Ramapo-Ajax Division): When we were thinking of how to make the presentation of the report of our committee more interesting we decided to have a talk by Mr. John Fellows, assistant chief metallurgist of the Ramapo-Ajax Division of the American Brake Shoe Company, who is thoroughly familiar with the metallurgy of manganese castings. We are happy to have Mr. Fellows with us today.

Manganese Steel*

By John A. Fellows

Assistant Chief Metallurgist, Metallurgical Department, American Brake Shoe Company, Mahwah, N. J.

The manganese steel well known for its service in trackwork was discovered in 1882 by Robert Abbott Hadfield, who at the time was working in the laboratory of the Hecla Works, a cutlery firm owned and operated by his father in Sheffield, England. His curiosity had prompted him to go beyond the efforts of earlier workers who had defined the useful manganese range to consist of alloys of not more than 2.5 percent.

* A condensed version of the actual talk given before the meeting.

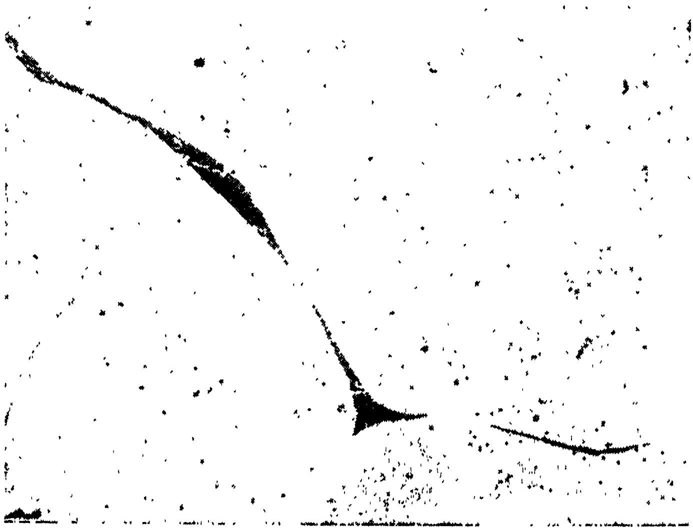

Fig. 2.—Grain Boundary Phosphides—0.284 percent P.

Grain boundary phosphide network in manganese steel containing .284 percent P. This brittle envelope seriously impaired strength and ductility at both high and ordinary temperatures. Etchant: Neutral sodium picrate.

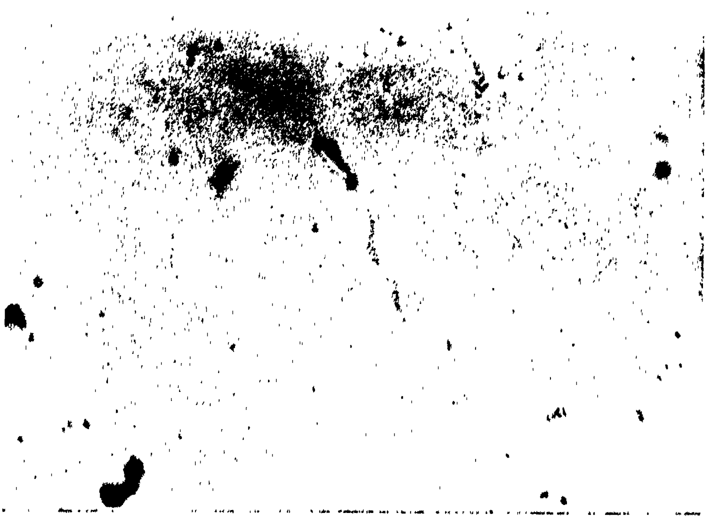

Fig. 3.—Grain Boundary Phosphides—0.073 percent P.

An isolated stringer of phosphide compound in manganese steel containing 0.073 percent P. This quantity has no effect upon room temperature properties but seriously decreased hot ductility. Etchant: Neutral sodium picrate.

Properties versus Chemical Composition

While the chemical composition can be altered appreciably without detrimental results, certain trends can be observed with changes in standard alloy content. Tensile strength and ductility both peak at about 1.15 percent carbon, with a decisive falling off of both below about 1.00 percent C and above 1.40 percent C, all measured at 12.5 percent to 13.0 percent Mn.

Manganese levels similarly affect strength and elongation when carbon is held constant at 1.15 percent. Below 11.0 percent Mn, both properties drop seriously, and above about 15.0 percent Mn there is a gradual decrease. The peak is a broad and flat one between about 13.0 percent and 15.0 percent Mn. The actual selection of a foundry aim point is based on the fact that the properties at slightly lower manganese levels are sufficiently close to the maximum to justify the saving in alloy cost.

The traditional limitation on phosphorus content always used to be 0.10 percent max. P. During the spring of 1941, we experienced serious foundry losses in one of our plants from cracked trackwork castings. After an exhaustive study of all possible foundry variables, it was concluded that the only correlating factor was a seemingly insignificant difference in phosphorus level. A series of laboratory melts to explore this possibility failed to show any detriment in room temperature properties below 0.10 percent P.

Since, however, the foundry defects pointed to a high temperature "hot shortness," hot tensile tests at 2100 deg. F. were finally selected as most informative. Using this technique it was demonstrated that phosphorus levels above 0.06 percent P were injurious to hot ductility, as is illustrated in Fig. 1. The explanation of this hot brittleness was found in the presence of a phosphide network at the grain boundaries (Fig. 2). This

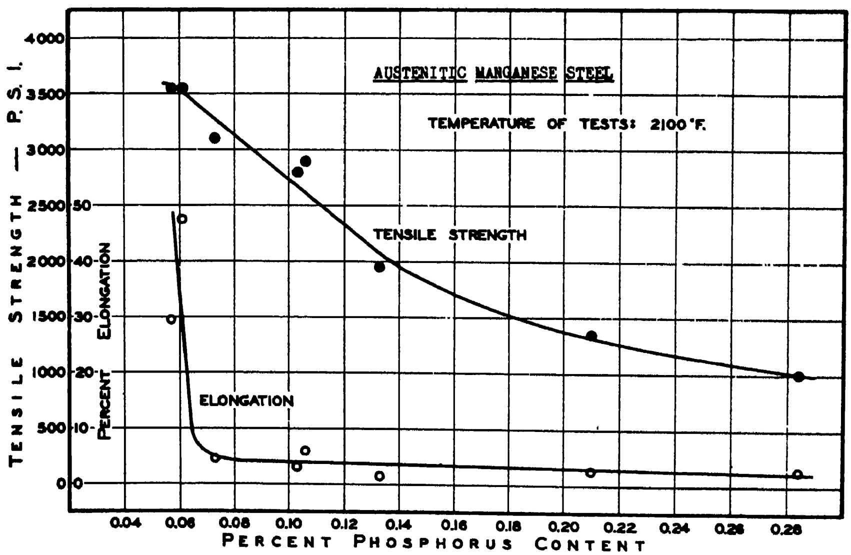

Fig. 1.—Effect of Phosphorus Content on Mechanical Properties at 2100 deg. F.

From data originally in the Amsco Bulletin and reprinted in Metals and Alloys, Vol. 15, No. 5, p. 834, May, 1942. Data requoted by H. S. Avery and M. J. Day, "Austenitic Manganese Steel", Metals Handbook, American Society for Metals, 1948 Edition, pp. 526–534.

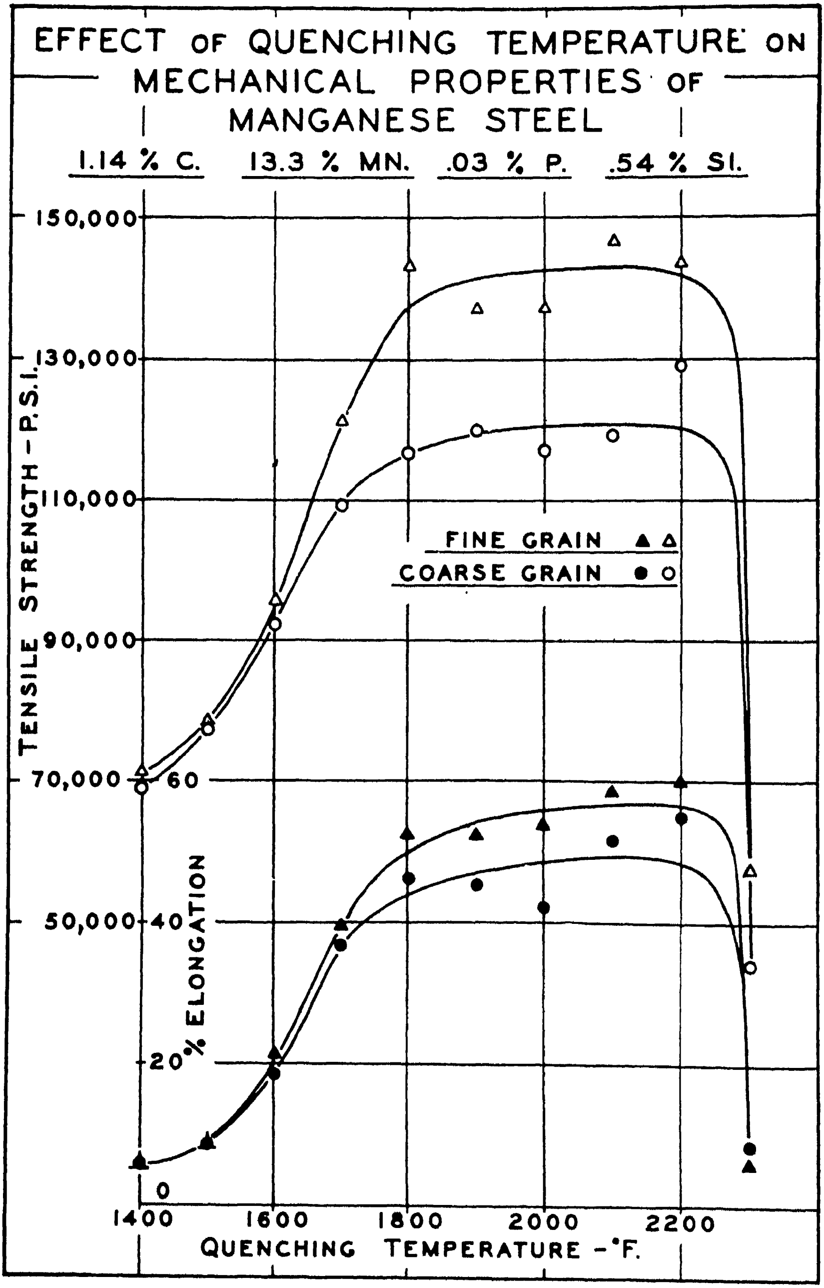

Fig. 4.—Effect of Quenching Temperature on Mechanical Properties. Response of cast manganese steel to the temperatures of heat treatment.

network, which was detected at contents as low as 0.073 percent P (Fig. 3), became increasingly weak and tender at very high temperatures, causing fracture with little elongation. The lowering of foundry specifications to 0.06 percent max. P. thus avoided scrapped castings from this source. Where casting shapes and sections do not contribute critical stresses during cooling in the mold, phosphorus levels up to 0.10 percent are, of course, acceptable with no loss of room temperature properties.

Properties versus Heat Treatment

The importance of the cooling rate of the water quench has been emphasized. An equally important factor is, of course, the temperature of heat treatment before the quench. Fig. 4 illustrates the effects on strength and ductility for fine and coarse-grained material. Below 1800 deg. F., the solution of carbides is not complete and these then persist in a detrimental form, regardless of the efficiency of the quench. The extreme loss in properties resulting from the 2300 deg. F. treatment represents the effect of "burning" —a term expressing a condition of partial fusion coupled with oxidation of the melted fraction, usually at grain boundaries.

While water quenching normally provides the desired cooling rate, when heavy metal sections are involved even this may be inadequate because of slow heat transfer through the metal wall. There will, therefore, be some maximum section beyond which castings cannot be properly quenched. We have been able to appraise this effect with the aid of a special test coupon which is quenched by a water jet on each end.[1,2] Cooling rates midway between the quenched ends match exactly the cooling rate of a plate of correlated thickness. On this evidence it is apparent that properties measured at this midpoint of the coupon will likewise correlate with the metal quality at the center of massive sections without the uncertainty of varying grain size which always provides a second confusing variable in studies of full sized castings. Fig. 5 illustrates the trend for a coarse grained heat. It is evident that sections above four in. in thickness show an increasingly inefficient quench.

One of the unique features of manganese steel is the relationship of strength and elongation. Hardenable steels show lowest elongation at maximum strength and vice versa. As is shown in Fig. 6, manganese steel does quite the opposite in presenting maximum ductility at maximum strength. (This graph represents 214 tests from 73 heats.) The major cause of the divergence is grain size. The fine grained structures yield the best combinations of strength and elongation.

Properties Particularly Important in Railroad Service

Notch Sensitivity

Highly stressed parts of carbon or alloy steels are generally extremely sensitive to surface flaws, cracks or any imperfections which provide local stress concentrations. These lead to early failures by fatigue. Manganese steel, however, possesses a very valuable insensitivity to notches. Wherever loading is severe cracks do form, but instead of progressing rapidly to failure, such cracks in manganese have an almost imperceptible rate of growth. Service in track can therefore continue for months with complete safety.

[1] Wilks, Avery, Cook, Further Developments of the End Quench Hardenability Test, Trans. American Society for Metals, Vol. 35, 1945, pp. 1–21.

[2] Wilks, Avery, and Cook, Relation of Quenching Rate and Hardenability to the Mechanical Properties of Several Heat Treated Cast Alloy Steels, Trans. American Society for Metals, Vol. 38, 1947, pp. 437–470.

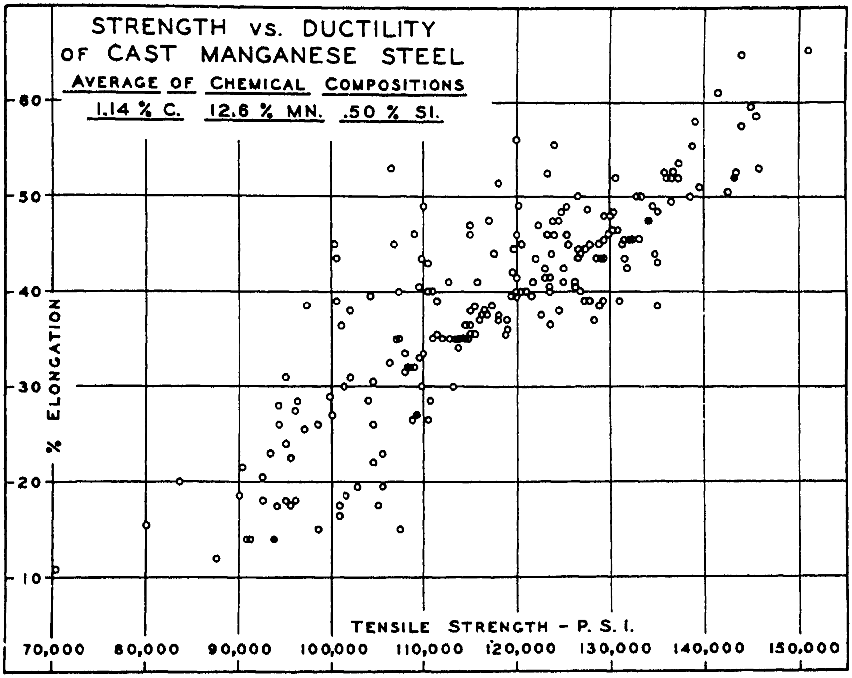

Fig. 6.—Relationship of Tensile Strength to Elongation for Manganese Steel. Unlike ferritic alloy steels, the ductility of Hadfield's manganese steel is greatest when the tensile strength is highest.

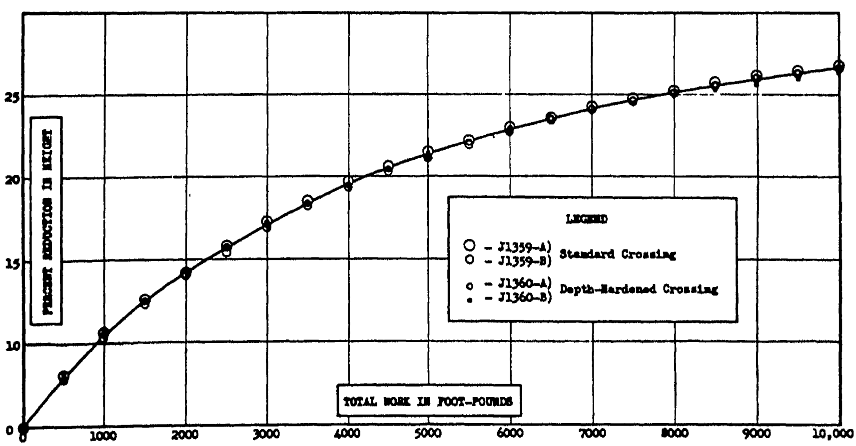

Fig. 7.—Behavoir of Welded Manganese Steel Under Repeated Impact. Flow of samples from welded manganese steel crossings when subjected to repeated 500 ft.-lb. blows. Note reproducibility despite differences in history.

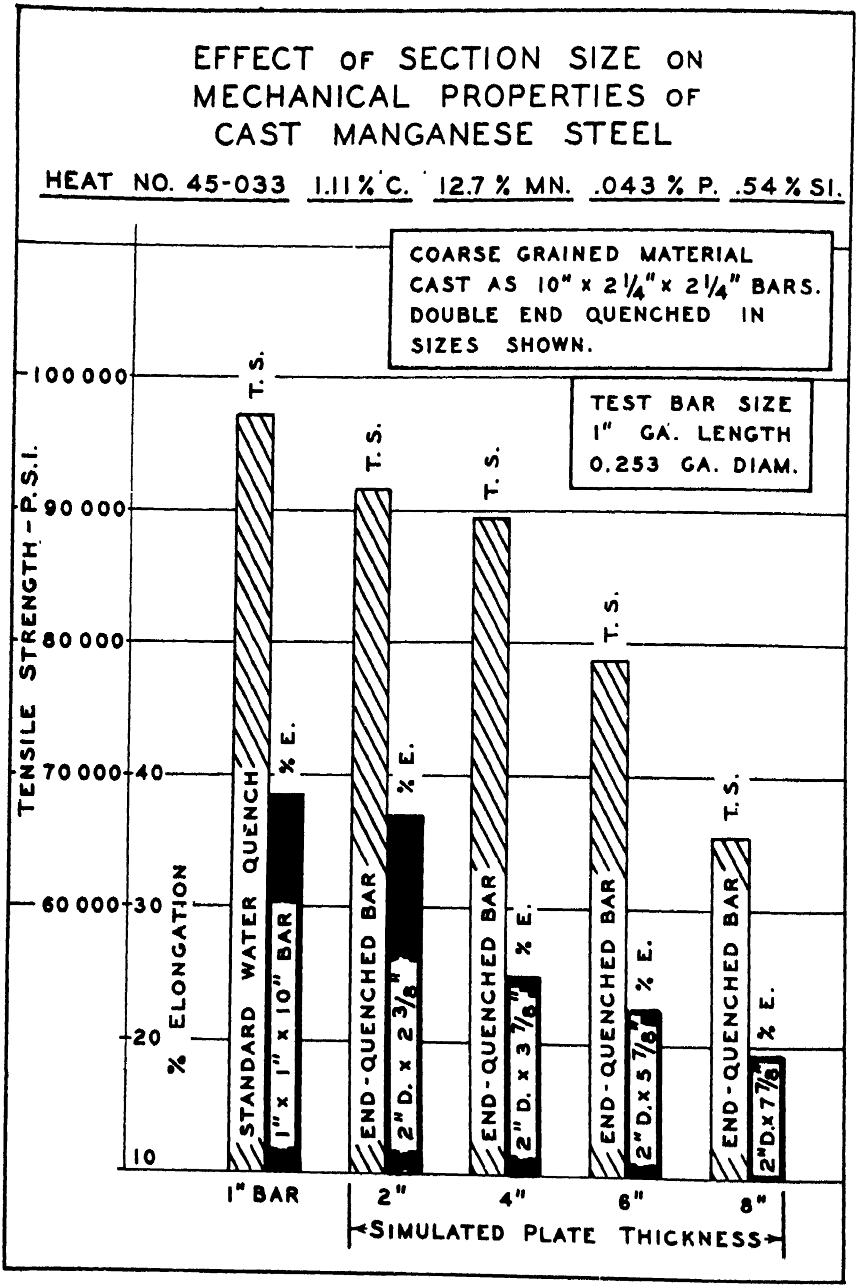

Fig. 5.—Effect of Metal Section Thickness on Mechanical Properties.

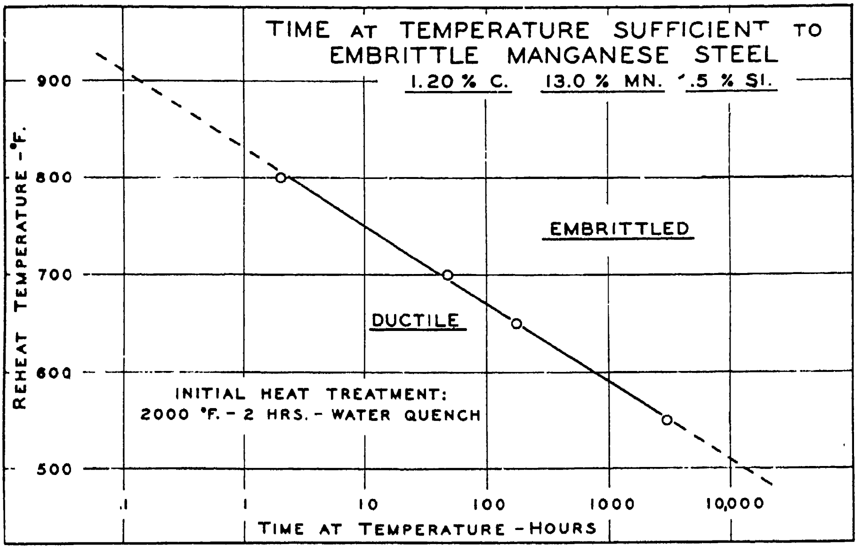

Fig. 8.—First Vestiges of Embrittlement versus Time at Temperature.

The embrittlement times illustrated refer to the first traces of evidence under the microscope of a change in structure. Measureable damage to properties will require longer reheating periods.

A further safeguard in welding is provided by the customary use of a nickel–manganese alloy rod (3.5 percent Ni). The nickel provides sufficient alloying effect to the fusion zone so that the austenitic state is readily retained in cooling. A lower carbon content in the rod also assists in thwarting any tendencies to precipitate excess carbides.

Work-hardened material is naturally more sensitive to reheating because of the probability of additional transformation and a consequent loss in ductility in withstanding thermal stresses. It is, therefore, standard practice to remove any work-hardened layer present by grinding before welding. When this is properly carried out, the quality of the weld will be independent of the method and degree of previous work hardening as has been illustrated in Fig. 7.

Chairman Caruthers: This concludes the report of the Track committee.

President Schwinn: Thank you, Mr. Caruthers, for the excellent report of your committee. We are also deeply indebted to Mr. Fellows of the American Brake Shoe Company, and to Mr. Magee once more, for their assistance in highlighting the work of this committee.

Mr. Caruthers, I understand that the presentation of this report concludes your service as chairman of the Committee on Track. The Association is indebted to you for the time and effort you have applied to the work of this committee during the last three years. Thank you and your committee. The committee is excused.

[Before recessing the meeting, President Schwinn announced that the convention registration for the first two days was 1634, compared with a registration of 1617 for the first two days at the 1948 annual meeting.]

(The meeting recessed at 5:25 p. m.)

(The meeting reconvened at 9 A. M. in the Grand Ballroom, with President F. S. Schwinn presiding.)

Fatigue Strength

To date, our laboratory has engaged in three separate appraisals of the fatigue strength of manganese steel employing different test methods in each case. The evidence at hand suggests that failure in fatigue may be quite sensitive to internal shrinkage even though minute. There are indications, for instance, that while an oxidized surface (which in a carbon steel might reduce the endurance limit by 50 percent) may only sacrifice 5 percent to 10 percent of the fatigue strength, internal micro-shrinkage on the other hand may halve the expected value. This work is incomplete and definite data cannot be reported as yet.

Impact Strength

Charpy V-notch impact tests indicate a room temperature impact strength of slightly over 100 ft.-lbs. when the notch (0.010 in. radius) is carefully ground to avoid work hardening. Contrary to tensile properties, coarse grain size in this test confers higher properties than fine grained material. Actual test results are quite sensitive to combinations of grain size and work-hardening effects. With a milled Vee (introducing flowed metal in the notch), a coarse grain sample has been known to withstand a 220 ft.-lb. blow without breaking.

Manganese steel also retains adequate impact strength at low temperatures. Tests at —100 deg. F. show an average value of just below 60 ft.-lb.

Work-Hardening

Repeated mention has been made of the hardening and stiffening created by plastic deformation of this material. This is most important for trackwork since it defines the rate at which a crossing point will be deformed under wheel impacts. We have found the behavior to be uniform and reproducible in terms of the impact energy applied. Fig. 7 is plotted from laboratory data to show the effect of repeated 500 ft.-lb. blows on a cylindrical sample. The change in slope of this curve, as the number of blows increases, illustrates the improved resistance to flow after the initial deformation.

Advantage is taken of this behavior in our organization's technique of depth hardening the points of manganese steel crossings before installation in track. Extra metal cast on the points permits work-hardening through flow from blows by a steam or air hammer. Subsequent removal of excess metal in the flangeways then provides a point which will exhibit minimum flow under the conditions of traffic and thus postpone the date of the first repair welding. Fig. 7 also provides evidence that this previous depth hardening has no influence on the properties of the welded point. Identical behavior is shown for welded samples of standard and of depth-hardened origin.

Repair Welding

The acceptability of welding techniques in rebuilding the receiving points of frogs and crossings has long been established. There are certain precautions, however, which should constantly be kept in mind.

Since austenite is moderately unstable at intermediate temperatures, the application of heat in welding should be kept to a minimum in terms of time and temperature. Fig. 8 shows the effect of reheating manganese steel to various temperatures as reflected by the *first* vestiges of a transformed structure. Since the alloy exhibits some sluggishness even in the higher temperature ranges, it is possible by rapid heating and cooling (the "mass-quench" or dissipation of heat within the casting is usually adequate if the heat input is held to the minimum) to avoid any measurable ill effects. With negligent welding, however, this could become a serious factor.

And we had other handicaps and disappointments, too. We first made a survey and review of the formal instructions issued by various railroads pertaining to the inspection of railroad bridges and the methods of recording and processing such inspection data. We found these instructions differ so widely as to inspection personnel, frequency of inspection and manner and form of reports that it was impossible for your committee to set up a modus operandi that would not conflict with the engineering, maintenance of way, or operating departments' formal instruction now in effect on the various roads.

We surmounted this hurdle like the proverbial Indian by by-passing it. This was done as indicated in the foreword of our report, and I quote: "It is the purpose of these instructions to describe the manner of inspecting a timber bridge; no attempt is made to set up the organization nor to fix the responsibility or the functioning of the various members of the organization."

This committee, therefore, has assembled the principles of timber inspection, which principles no doubt were known and used by Noah when he built the Ark, the same principles which were in evidence when Solomon's cohorts constructed the temple which bore his name, and the same principles which today are known to every practical and skilled bridge man; these principles we have arranged and set down in detailed logical order of sequence. These, we take pride in presenting to this worthy convention.

Chairman Lund: Mr. Showalter's committee, I am sure, will be glad to receive comments from the membership during the coming year regarding the text of these proposed instructions.

Assignment 6—Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints, was presented by J. V. Johnston (Gulf, Mobile & Ohio), subcommittee chairman.

Mr. Johnston: In compiling this report, your committee canvassed 68 railroads in this country and Canada. The information contained herein, it is believed, covers the methods now in use on the railroads. As of this date, it was found that most of the railroads prefer to use common-sense methods for fireproofing, such as the maintenance of sound timber, the removal of combustible material, and the cutting and removal of weeds and grass from around bridges. Most of the railroads feel that the added expense of the various special methods described is not, for the most part, justified.

Chairman Lund: The subject of fire prevention has always been of real concern to every railroad man, recent years have seen increased interest in the subject, and a number of articles have appeared in various publications dealing with the problem.

Subcommittee 6 presented information last year on this subject with respect to building materials treated with fire retardant coatings. Your committee felt that the Association would welcome a brief and clarified discussion of fire retardants for wood and the progress that has been made in them, by an authority on the subject. We therefore invited Mr. T. R. Truax, chief of the Division of Wood Preservation, Forest Products Laboratory, to talk to you today. It is a great pleasure for me to introduce to you, Mr. T. R. Truax.

Discussion on Wood Bridges and Trestles

(For Report, see pp. 431–440)

President Schwinn: The meeting will please come to order. Will the members of the Committee on Wood Bridges and Trestles please come to the platform? The chairman of this committee is Mr. C. V. Lund.

Chairman C. V. Lund (Chicago, Milwaukee, St. Paul & Pacific), introduced the committee's report as a whole, and then called upon the various subcommittee chairmen, in turn, to present their specific subcommittee reports.

Assignment 1—Revision of Manual, Nelson Handsaker (Northern Pacific), subcommittee chairman. In the absence of Mr. Handsaker, Mr. Lund presented the report, offering one at a time, for adoption, the various recommendations of the committee for changes in the Manual.

(Each motion, as presented, was seconded, put to a vote and carried.)

Assignment 2—Grading Rules and Classification of Lumber for Railway Uses; Specifications for Structural Timber, Collaborating with Other Organizations Interested.

Chairman Lund: Your committee presented some material last year in regard to working stresses for classes of structural timber, which it appeared could be made. We reported that we hoped to be able to offer definite recommendations this year. This subject is quite involved. We did not make the progress we had hoped to. There is good reason to believe, however, that we will report on this subject next year. It is expected that some rather important revisions in the Manual will be offered.

Assignment 3—Specifications for Design of Wood Bridges and Trestles. J. P. Dunnagan (Southern Pacific Company), subcommittee chairman, presented the report.

Mr. Dunnagan: Your subcommittee, after consideration for a year and a half, has several changes in Manual material under consideration, but because of their being of an editorial nature, it has been decided to postpone them until such time as other material in these pages requires change.

The committee presents a table of bolt values based upon the data given in paragraph 307 and Tables 707 and 708 of the general specifications.

(Mr. Dunnagan then read the proposed revision to the Specifications for Design of Wood Bridges and Trestles for Railway Loading and moved that they be adopted. The motion was seconded, put to a vote and carried.)

Assignment 5—Instructions for Inspection of Timber Trestle Railway Bridges, was presented by J. R. Schowalter (Missouri Pacific), subcommittee chairman.

Mr. Showalter: Our report may not be as learned or profound as other reports being presented here, may not be as revolutionary or precedent-breaking as some, but we are sure it is the driest and most tedious of all. We do not have a single new improvement to offer which will reduce the laborious tedium of previous inspection methods. We know of no radar equipment, no sonic sounding machine, no Geiger counter, which will mechanically record the defects and weaknesses of a timber trestle.

This failure, in spite of diligent research on the part of your committee in various plants, and consultations with expert personnel of the Forest Products Laboratory in Madison, Wis., the Underwriters Laboratories in Chicago, Koppers Treating Plant at Orrville, Ohio, and a large long-leaf pine mill near Alexandria, La.

soluble chemicals exhibit fire-retardant properties (7)* when present in wood, but because of cost limitations or various objectionable characteristics, comparatively few are considered practical. Among the most commonly used chemicals are monobasic and dibasic ammonium phosphates, ammonium sulfate, borax, boric acid and zinc chloride. These are usually combined in various proportions in treating formulas. The chemicals in water solution are usually injected into wood by full-cell pressure processes to obtain predetermined absorptions. Dipping, soaking, and other superficial treatments do not usually give either sufficient absorptions or penetrations to yield significant fire-retardant effects.

More than 50 years ago wood was being treated commercially by pressure impregnation. The first important demand for fire-retardant treated wood in this country apparently came from the U. S. Navy for use in ship construction. Shortly thereafter the city of New York gave impetus to the embryo industry by adopting a revised building code, which required that wood, used in the construction of buildings over 150 ft. in height must be treated to make it so-called "fireproof." In spite of the fact that much further investigative and development work has been done since that time, the industry has not continued to grow or expand significantly or in proportion to the need for protection of wood against fire. The largest production of fire-retardant treated wood occurred during World War II. Its principal uses were for the construction of dirigible hangars and for shoring aboard ships. In 1943, 65 million board feet were treated by pressure processes, but by 1946 the production had dropped to less than 5 million. In 1948 it had again increased to about 9½ million board feet. (3).

The slowness with which fire-retardant treated wood has been accepted and used is due to several factors. First, it has been difficult to demonstrate its performance under actual fire conditions and to assess the values and advantages of fire-retardant treatments in accepted terms of savings. When trestle timbers are treated with a wood preservative and put into service they are immediately placed under conditions that favor decay, so it is possible to observe the effectiveness of the treatment in retarding decay. On the other hand, when wood is treated with a fire-retardant and placed in service it is not exposed immediately to fire, and it may never be. Thus, there is much less opportunity to observe its ability to withstand fire in service. Relatively large amounts of fire-retardants, based on pounds of chemical per unit volume of wood, must be used to get significant fire-retardant effects. The higher concentrations of chemicals used in fire-retarding treatments are more apt to cause problems than the lower concentrations used in preservative treatments. For example, there are possibilities of reduction in strength of the wood, increased hygroscopicity, interference with painting and other subsequent processes or operations, and corrosion of metal fastenings. However, the chief drawbacks to a more extensive use of fire-retardant wood apparently are: (a) Insufficient recognition of the value of fire-retardant treated wood by engineers, architects and builders; (b) lack of generally accepted standards and specifications; and (c) cost of treatment that is not offset by compensating savings in insurance and amortization rates.

Lumber and timbers are the principal forms in which wood has been pressure treated with fire-retardants. The treated lumber has gone largely into interior trim and doors where building codes or regulations require such treatment. Treated timbers have found specialized uses where fire hazards are considered critical or where possible fire damage may be large. Since the fire-retardant chemicals are water soluble and hence more or less leachable, the usefulness of treated material under exterior exposure and periodically wet conditions has not been well established.

Some progress has been made in the development and adoption of standards and specifications for fire-retardant wood. In the AREA Proceedings, Vol. 45, 1944, page 166,

Making Wood Fire Retardant

By T. R. Truax
Chief, Division of Wood Preservation
Forest Products Laboratory, Madison, Wisc.

Your chairman suggested that it would be of interest to the members of the committee if I would review briefly fire-retardant treatments for wood in a broad way, indicating their fields of usefulness or potential use. He has further indicated an interest in having me do a bit of crystal ball gazing as to possible future developments in new materials and new approaches that hold promise. I make no claims, however, as a prophet.

Limitations in Fire-Retardant Treatments

The railroads were early users of preservatively treated wood and have taken advantage of its economies rather fully. The advantages of the use of woods effectively treated against decay and insects have been demonstrated and the economy of treatment can be rather closely calculated in actual savings. Consistent with this combination of pioneering spirit and sound business principles, it is but natural to expect that the railroads would have a substantial interest in the better protection of wood in their properties against fire, and in ways and means of accomplishing their desirable objective. However, the advantages of treating wood with fire-retardant chemicals have not been, and probably cannot be, so clearly demonstrated as they have for preservatively treated wood. In fact, it can be safely said that the protection of wood against fire and its deterioration under high temperature cannot be so successfully accomplished as can the protection of wood against decay and insects.

In discussing fire-retardant treatments for wood it should be kept in mind that there are two distinct aspects of fire performance. One is fire spread, and relates to the rapidity or freedom with which fire spreads over a surface that has been ignited. The other may be termed fire resistance, and relates to the tendency of fire to penetrate a member or structure. The manner and extent to which the spread of fire is retarded and in which penetration of fire is resisted are often closely related. In structures, such as bridges and houses, both phases of fire performance are largely dependent upon the size, form, and arrangement of the materials of the structure and the character of the igniting fire, as well as the specific properties of the construction material itself.

Wood chars when exposed to fire or fire temperatures, irrespective of whether it has had a fire-retardant treatment or application. The rate of charring or destruction and the transmission of heat through wood may be improved slightly by fire-retardant treatments, but the most significant benefit comes in reducing or delaying the spread of fire. Fire-retardant treatments and applications can only be expected to retard the burning and spread of fire to the point where the wood will not continue to burn when the ignition source is removed or exhausted.

Two general methods are available for improving the performance of wood under fire conditions. One method consists of an impregnation treatment that deposits chemicals within the wood. The other is the application of coatings or layers of noncombustible materials over the surface of the wood.

Impregnation Progress

It has long been known that the property of dry wood to burn freely can be substantially changed by its impregnation with fire-retardant chemicals. Many water-

* Numbers in parentheses refer to literature cited at the end of this report.

Interior-type Fire-Retardant Coatings

Most fire-retardant coating preparations that have been developed are of value primarily for interior use and are not durable under exterior exposures. In general, these coatings can be grouped into the following broad classifications:

Solutions of water-soluble chemicals.—Plain water solutions of effective fire-retardant chemicals, such as the ammonium phosphates, mixtures of ammonium sulfate and monoammonium phosphate, borax and boric acid, have been offered as fire-retardant coatings. While strong solutions of these chemicals possess inherently good fire-retarding properties, most woods will absorb only a relatively small quantity of solution with a surface application, and the degree of protection secured by such treatment is low. Only by several applications of strong solutions of these chemicals can even a moderate degree of fire-retarding effectiveness be obtained.

Solutions of sodium silicate, either alone or in combination with inert materials, have formed the basis of a number of proprietary fire-retardant paints. While fresh sodium silicate coatings are quite effective against fire spread, they lose their effectiveness with time, and especially under damp conditions.

Suspensions of chemicals in water solutions.—A new type of fire-retardant coating developed at the U. S. Forest Products Laboratory (10) consists essentially of an aqueous gel of sodium or diammonium alginate and fire-retardant chemicals. The use of the alginate makes it possible to incorporate into the coating mixture a quantity of fire-retardant chemical considerably in excess of that required to saturate the solution. The ammonium fire-retardant salts and mixtures of borax and boric acid are compatible with the gel. The consistency of the preparation is such that sufficient material can be applied in two or three coats to provide good fire-retarding effects.

Coatings similar to the borate alginate preparations may be made by using methyl cellulose as the thickening agent or vehicle. It may be used with borax, boric acid, or mixtures of borax and boric acid, but not with ammonium phosphate because the latter chemical causes coagulation.

Linseed oil base paints.—Linseed oil paints of good fire-retarding effectiveness have been prepared at the Forest Products Laboratory by replacing a substantial portion of the pigment with finely ground borax (10). Heavy coatings of this type of paint are required to afford good degrees of protection against the spread of flame. Commercial paints of this type are available.

Synthetic resin coatings.—Certain types of synthetic resins, such as phenol formaldehyde, urea formaldehyde, ethylidene urea-formaldehyde, and dicyandiamide in combination with ammonium phosphate, provide good protection against flame spread. As with a number of other coatings, their effectiveness is due mainly to the swelling of the resin to a frothy mass and hardening when exposed to heat, and its protection against combustion by the ammonium phosphate present. Some of the more effective commmercial fire-retardant paints are of this type.

Casein and whitewash paints.—Casein and whitewash paints are generally regarded as having some fire-retarding properties, especially when applied in heavy coats. The degree of protection is increased when borax is introduced in the formula, but even then three coats of such preparations are not of the same order of effectiveness as a similar number of coats of the better coatings of other types previously described.

Exterior Type Fire-Retardant Coatings

One inherent major weakness of all the preparations described so far is their inability to retain effectiveness under exposure to water, due to the removal of the water-soluble

(December 1943) of the AREA, Committee 6 presented a report on Fire-Retardant Wood for Railway Buildings, in which a specification was proposed for the treatment of timbers and lumber (1). Other efforts have resulted in the proposal, and in some cases the adoption, of other specifications, classifications, and standards by the ASTM (2), U. S. Navy Bureau of Yards and Docks (8) and Bureau of Ships (9), Underwriters Laboratories, U. S. Forest Products Laboratory, and others. While various test procedures and requirements have been proposed, and in some cases put in effect, there is still much lacking and needed for a better correlation and understanding of the significance of such tests and requirements in terms of performance under actual fire conditions.

Some preservatives add fire-retardant properties to wood, but not to a significant degree unless the retentions are substantially in excess of those normally used for protection against decay and insects. Borax, boric acid, zinc chloride, and most arsenic compounds are of this type. When used alone, or preferably in combination with other effective fire-retardant chemicals, they have formed the base for most current treatments of wood in which combination decay and fire-retardant properties are sought. Several such combination treatments are available commercially or have been patented. Although further evaluation of these combined treatments are needed, they appear to offer the best hope at the present time of substantially reducing by treatment the fire hazard in wood bridges and similar structures.

One of the more important questions upon which further information is needed for such treatments is the permanence of the fire-retarding qualities. It has generally been assumed that, when exposed to the weather, the fire-retardant effectiveness of the treated wood gradually decreases through the leaching of the chemicals. However, service data are not available to indicate performance from the fire protection standpoint, and only insufficient data are available on leaching rates, from which estimates might be based.

The results of some tests have indicated that the rate and amount of leaching in contact with water can be materially and significantly reduced by applying surface coatings or a sealer to the treated wood. The California Division of Highways reports (5) that a sand-cement-paint composition was highly effective in preventing the leaching of zinc chloride, and in preserving the fire-retardant properties, but was somewhat less effective for certain other preservatives. Bescher, Henry, and Dreher also report reduced leaching of chromated zinc chloride compounds when the treated wood was given a second shallow impregnation with a "fire-retardant, water-repellent sealer" (4). There appears, therefore, to be substantial evidence that the fire-retardant properties of salt-treated timbers can be substantially preserved under rather severe service conditions.

Fire-Retardant Coatings

Many coating materials provide fire-retarding effects to wood in varying degree. (10). As in the case of impregnation treatments, the degree of protection provided by coatings is related to the inherent properties of the product, the amount and thoroughness of application, and the severity of the fire exposure.

Fire-retardant coatings have received even less recognition than impregnation treatments because of the lack of standards enabling the purchaser to know whether he was purchasing an effective and durable product or one of little or no merit. Some progress has, however, been made in getting general agreement upon standard methods for evaluating the effectiveness of fire-retardant coatings. Some of the proposed methods are described in Research Bulletin No. 32, Fire Hazard Classification of Building Materials, by Underwriters Laboratories, Inc.; Federal Specification SS-A-118, Acoustical Units; and Forest Products Laboratory Report R1443, Fire Test Methods Used in Research at the Forest Products Laboratory.

In the rapidly expanding fields of resin and plastics development, and the modification of wood by chemical means lie a hope and possibility that better treatments and methods will be found for protecting and making wood more resistant to fire under various service conditions.

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President Schwinn: Thank you, Mr. Truax.

Chairman Lund: I am sure that the remarks we have just heard have enlightened us on a subject that is not too well understood.

Assignment 7—Statistics Relating to Wood Bridges and Trestles, A. L. Leach (Illinois Central), subcommittee chairman.

Mr. Leach: Due to an error in the original manuscript, under section 6, at the top of page 440, the headings, "Timber and Piling" should be omitted, and the numbers under the heading "Piling" should be moved to the left, in line with the other numbers in this section.

fire retardants. Some will offer slightly more resistance to moisture than others, but none of them is considered satisfactory for exterior exposure.

So far as is known, no water-insoluble compound has been found that is equal in fire-retarding effectiveness to such water-soluble compounds as ammonium phosphate, borax, and sodium silicate. Some progress, however, is being made in the formulation of coatings that are durable under exterior exposure and provide some protection against flame spread. Compounds of low water solubility that have fire-retardant properties are zinc borate, chlorinated paraffin, and chlorinated rubber.

In recent years a number of proprietary paints have appeared on the market with chlorinated paraffin as the base. These paints, while possessing moderate fire-retarding properties, do not give a performance equal to that of the better interior paints. A limited amount of testing at the Forest Products Laboratory has shown that a zinc-borate-linseed-oil coating has moderate fire-retarding effectiveness. While the development of these types of coatings for exterior use is encouraging, none of them has the degree of effectiveness that warrants placing a great deal of confidence in its ability to check fire spread under moderate to severe fire conditions.

Still other water-resistant types of materials with some fire-retardant properties have found occasional use or offer possibilities for the protection of wood. AREA Committee 7 reports that several railroads have developed, and have used rather extensively, a special patented asphalt compound which gives promise of being especially fire resistant. Bituminous-base compounds, in which asbestos and other noncombustible, inert materials are included, seem to be promising as fire-retardant coatings for wood where appearance is not especially important.

Comparison of Impregnation and Coating Methods

Good fire-retardant effects in wood can be obtained with both impregnation and coating applications. For new construction and the repair of existing structures, pressure impregnation with effective fire-retardant chemicals seems to offer the best possibility of obtaining lasting fire-retardant effects in wood structures. The quantities of material used and the initial costs involved are relatively high and the possibility of adversely affecting the strength and other properties of the wood are greater than with coatings. For existing structures, surface applications offer the principal means of increasing their fire-retardant properties. Coatings are more temporary in effect but are renewable and have less possibility of affecting the wood adversely.

Possibilities for Improvement

There are other developments and research results that hold promise that fire-retardant treatments and coatings may ultimately be available that are satisfactory under exterior conditions. Significant developments have apparently been going on in the textile field in the production of washable fire-retardant fabrics (6), some of which may be applicable to wood. One of these is a urea-ammonium phosphate treatment, in which the phosphate is believed to combine chemically with the cellulose of the fiber and thereby produce an insoluble compound that is fire-retardant.

Another new flame-retardant material is recommended by the Du Pont Company for the treatment of fabrics. The active flame-retarding constitutents are reported to be salts of titanium and antimony, which react with the cellulose molecule, changing it chemically but not physically. A similar result might be possible in the treatment of wood.

The metal ammonium phosphates, such as those of zinc and copper, are highly insoluble and have some fire-retardant effects, but their potential use has not been fully explored.

of existing laws or orders, and by labor organizations in their crusades for new and additional regulations.

Since the tabulation was published originally, California has revised its clearance order, Tennessee has adopted a clearance law, other states are faced with laws where none now exist, while still others are considering revisions.

It is unfortunate that in processing the tabulation for printing the first figure 2, in the figures 22, has been obliterated from the first seven of the General Overhead Clearances for Tunnals.

To get better coverage, the consist of the committee has been expanded, and immediate results of a check by the enlarged committee reveal several errors and omissions in the tabulation, as follows:

	Should Be	*As Shown*
California		
Main Freight Tracks	14′-0″	13′-0″
Team Tracks in Pairs	13′-0″	13′-6″
Freight Platform 4′-0″ high	7′-6″	7′-3″
Overhead Clearance—Bridges	22′-6″	22′-0″
Indiana		
General Side Clearance, Buildings, Structures, etc.	8′-0″	7′-0″
General Side Clearance, Bridges	8′-0″	7′-0″
South Carolina		
Statutes enacted in 1942. Should be added, which provide:		
Overhead Clearances		
Bridges—General	22′-0″	
Lesser clearances permitted in quadrants	No.	
Side Clearances		
Bridges—General	8′-0″	
Lesser clearances permitted in quadrants	No.	

Your committee is hopeful that the above corrections may appear on the chart as published in the proceedings. It feels that in view of the activity toward clearance regulations that a tabulation with such wide distribution and use should be as accurate as possible.

R. P. Hart (Missouri Pacific): I wish to inquire of the committee as to the reference about Kansas clearances. In the second column of the table, Kansas is shown as having no clearance law or statute. I think the committee will find there is an old statute in Kansas which requires all structures built over railroad tracks to be not less than 22 ft. above top of rail. For the benefit of anyone expecting to build a bridge over a railroad track in Kansas, I suggest that be noted in the tabulation.

President Schwinn: Mr. Hart, can you give a reference to the statute?

Mr. Hart: I don't have the reference with me, but I will be very glad to furnish the reference to the chairman of the committee.

President Schwinn: Please, if you will do so.

Chairman Harris: Thank you, Mr. Hart. I will take steps to obtain that information and will see that it gets into the revised table this year.

Assignment 5—Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection, S. M. Dahl (Chicago, Milwaukee, St. Paul & Pacific), subcommittee chairman.

Mr. Dahl: To the present time, very little attention has been directed toward the question of lean or tilt due to uneven deflection of the springs. It has been generally assumed that the center line of equipment is at all times perpendicular to the plane of the tops of the rails, on curves as well as on tangents. It is felt that this assumption may

Since this summary was made, replies from two additional railroads have been received, reporting a total of 535,974 track feet of timber trestles in service. Letters are to be sent by your committee to the railroads which have not replied to its questionnaire, so a complete summary may be published next year.

Chairman Lund: I hope many of you will take time to review the tabulations given. They are of considerable interest, though incomplete. The Proceedings of the second Annual Convention of this Association record the remarks of President Wallace, who said with regard to timber bridges, "We cannot go on indefinitely renewing them in wood—timber is becoming scarcer and more expensive year by year, and it is quite a live question as to how we can economically and permanently deal with these bridges."

The following year this committee reported, "The day is past and gone when a wooden bridge can be considered as a desirable structure on a railroad, and in putting them in we do so with almost an assurance that they will be replaced by a permanent structure within the life of the first timber used in the construction." That was in 1902.

The impressive figures of the total amount of timber trestle in service today, and the indications of continued use are evidence that timber structures have, on the contrary, been found to be the most economical construction under many conditions of service.

Mr. President, this concludes the report of this committee.

President Schwinn: Our thanks are extended to Mr. T. R. Truax, chief of Division of Wood Preservation, Forest Products Laboratory, for his most interesting report.

Mr. Lund, thank you, for this informative report presented by your committee, which is now excused with the thanks of the Association.

Discussion on Clearances

(For Report, see pp. 341–342)

(President F. S. Schwinn presiding)

Chairman A. R. Harris (Chicago & North Western): In addition to the five subjects shown in our report, a new subject, No. 6—Methods for Measuring Clearances, has been approved. The committee also has under consideration a new subject, Clearance Tolerances to be Allowed in Handling Rolling Equipment and Open Loads on Main and Other Tracks, collaborating with the Mechanical Division.

The personnel of Committee 28, has been increased from 23 members to 42. The enlarged personnel was requested primarily to obtain a more complete geographical representation for assignment 4—Compilation of the Railroad Clearance Requirements of the Various States, and to assemble information as to Commission rulings as well as statutory requirements.

Assignment 1—Revision of Manual, J. E. Fanning (Illinois Central), subcommittee chairman.

(A motion put by Mr. Fanning to adopt the one recommendation of the committee was seconded, put to a vote and carried.)

Assignment 4—Compilation of the Railroad Clearance Requirements of the Various States, C. D. Horton (Erie Railroad), subcommittee chairman. In the absence of Mr. Horton, the report was presented by R. C. Nissen (Southern Pacific).

Mr. Nissen: The tabulation presented has received wide distribution since it was first issued two years ago, and is now being used not only by railroad engineering departments, but also by public utility commissions or other state bodies in their review

built in the early 1900's. Despite this excellent record, the indications of concrete deterioration both in structures and in pavements are much too frequent.

The causes of deterioration of portland cement concrete are many and varied. Included are poor design, poor workmanship during construction, and the use of inferior materials. There are many old concrete structures still giving service which also are in distress because of disintegration and deterioration of the concrete and require costly annual maintenance. If certain types of disintegration and deterioration can be corrected or retarded by the application of some type of surface waterproofer, it follows that such a procedure would be of great economical importance in prolonging the service life of a structure. It is also evident that the use of waterproofers will not necessarily retard certain types of concrete deterioration, for instance that caused by water seeping through from the inside of a retaining wall, wing wall, or abutment.

Importance of the Problem

A great deal of information has been obtained in recent years in the evaluation of portland cement concrete pavements by field performance surveys. In 1939, Cantrill and Campbell[1] called attention to the poor service record of certain pavements in Kentucky in which coarse aggregate of inferior quality was used. This work was supplemented by laboratory investigations and the authors recommended the use of a specification for coarse aggregates which restricted the use of certain types of inferior materials. Gibson,[2] in 1938, reported on the map-cracking and inferior performance of pavements constructed with sand-gravel aggregates in Kansas. He, too, followed the field work with laboratory studies and concluded that freezing and thawing tests were more useful in evaluating the durability characteristics of coarse aggregates than were the sodium and magnesium sulfate soundness tests. At a later date, White and Peyton[3] reported on the condition of a large mileage of concrete pavements in Kansas which were giving good performance when constructed with certain specific aggregates but poor performance when constructed with certain other aggregates.

The published information available on the performance of portland cement concrete in railroad and highway structures is not so abundant as the information on highway pavements. One of the early references to disintegration of concrete in structures is contained in a Highway Research Board committee report authored by McCown[4] in 1931. Several state highway testing and research laboratories reported on the significance of the sodium sulfate and freezing and thawing tests for mineral aggregates. In this assemblage of data, Myers reported inferior field results in the use of Cedar Valley limestone when used in concrete in Iowa. At the same time, the Illinois Highway Department reported poor resistance to the sodium sulfate soundness test of Cedar Valley limestone and mention is made of a serious failure of one concrete bridge constructed with this aggregate. The report contains excellent photographs showing disintegration of concrete in highway structures. In 1930, the American Railway Engineering Association Committee on Masonry reported on variables which influence the quality of concrete and mention is made of unsuitable aggregates. The report contains some excellent photographs of concrete deterioration.

In 1945, Jackson[6] reported on the distintegration of bridge concrete in the West. The report discusses and defines four types of deterioration and a large number of photographs are used to supplement the word descriptions. Mr. Jackson recommends a relatively low mixing water content for the concrete mix and the use of air entrainment where concrete is likely to be exposed to frost conditions. He recommends further that

lead to serious error, especially so since the advent of the soft steel spring and other innovations in equipment design.

Another factor which makes this subject more important at the present time is the practice of using up to three in. of unbalanced superelevation on curves. This must, of necessity, result in uneven deflection of the springs. Some tests have been made which indicate that the common track center of 13 ft. might not be sufficient on certain curves under certain conditions.

The matter of end throw due to lateral play and wear is presently being held in abeyance, and attention directed instead to lean or tilt due to spring deflection. A study is being made in cooperation with Mr. G. M. Magee, in collecting and analyzing available data pertaining to this subject; also in planning future tests.

The committee does not feel that it has progressed the subject enough to present a report at this time, but hopes to have some definite information before the next convention. It was felt however, that the foregoing resumé of what the committee hopes to accomplish would be of interest at this time.

Chairman Harris: This completes the report of Committee 28.

President Schwinn: Thank you, Mr. Harris. Your committee deserves the gratitude of the Association for the constructive work it is doing in a field that offers little opportunity for glamour. You are now excused.

Discussion on Waterproofing

(For Report, see p. 362)

(President F. S. Schwinn presiding)

Chairman R. L. Mays (New York, Chicago & St. Louis) presented a brief synopsis of the committee's report on Assignment 3—Waterproofing Protection to Prevent Concrete Deterioration, and then said, as follows:

The test work of the committee at Purdue is carried on under the direction of Professor K. B. Woods, associate director, Joint Highway Research Project, and Professor of Highway Engineering. Mr. Woods has had a great deal of experience in connection with the deterioration of concrete, and through his extensive research work and that of his staff, he has gained a wide field of experience with conditions affecting concrete deterioration.

Your committee has arranged with Professor Woods to give an address at this time, and we are very grateful that he accepted this invitation—Professor Woods.

The Use of Waterproofing Paints for Minimizing Structural Concrete Deterioration

By K. B. Woods, J. B. Blackburn and D. W. Lewis
Purdue University

Introduction

The many thousands of old portland cement concrete structures and the thousands of miles of old highway pavements which are still giving good service are evidence of the good durability characteristics of well-made portland cement concrete. The first concrete street pavement in America was constructed in Bellefontaine, Ohio, in 1891, and is still in use. There are many railroad and highway structures, still giving service, which were

Map-cracking on a concrete pavement surface which occurs when certain river gravels are used as the coarse aggregates. The dark areas which border some of the larger cracks indicate the presence of moisture which has traveled through the concrete from the wet subgrade below.

The factors which determine the durability of concrete, when subjected to a given condition of exposure, may be divided into three general categories. For the purposes of this discussion, the major factors are classified as follows: (a) the design of the structure and the concrete mix, (b) the workmanship in construction, and (c) the quality of the materials used in the concrete.

Design of the Structures and Concrete Mix

Design factors that may affect the durability of a given structure are, in general, widely recognized. However, some of the more important items will be discussed briefly.

In the case of concrete pavements, failure to provide for adequate subgrade drainage is a major factor in increasing the severity of weathering. Many examples exist of direct correlation between the performance of a pavement and the drainage characteristics of the subgrade upon which the concrete is placed. The result of construction on poorly drained materials, of course, is to make more moisture available for the concrete to absorb, thus increasing the severity of weathering (particularly freezing and thawing). The effects are particularly noticeable in cases where the concrete is inherently susceptible to such weathering because of the nature of the materials used.

In a similar manner, failure to provide proper drainage for bridges or other structures may cause exposure of the concrete to unnecessarily severe water conditions and resultant aggravation of the effects of the natural weathering processes. Among the "sins of omission" in the design of concrete structures, the following might be listed as highly

specifications for the portland cement be modified where alkali-aggregate reactions are likely to be encountered. Tremper[6, 7] reports deterioration of concrete both in structures and in pavements when aggregates from the Mount Rainier region of Washington are used. The reports stress the importance of the chemical incompatibility of certain aggregates and cements.

The Committee on Waterproofing, AREA, has been interested in the development of maintenance procedures for retarding concrete deterioration for many years. It is of historical interest to note that a 1927 report of the Special Committee on Waterproofing refers to the use of a membrane type of waterproofing for use on bridge floors. In addition, the Committee on Masonry, AREA, has been much interested in the subject of deterioration. This committee likewise refers to integral compounds for waterproofing as early as 1927.

In 1948, Mrs. Ruth Terzaghi presented a paper before the AREA annual convention on the general subject of concrete deterioration. This paper presented a historical review of the use of concrete in structures and discussed some of the problems of concrete durability.

It is apparent from an inspection of the literature that concrete deterioration in regard to highway and railroad bridges is important. Shorter life and increased maintenance alone justify intensive study of the subject, and where deterioration is already apparent, the use of corrective procedures such as waterproofers is very important economically. Although it is difficult to estimate the dollar cost, it is nevertheless true that the problem is costing hundreds of thousands of dollars per year.

Many research organizations, testing laboratories and federal agencies have been actively engaged for many years in studying the problem of concrete durability. As already mentioned, the AREA Committees on Masonry and Waterproofing have sponsored a great deal of research, and much work has been done on the problem.

In the final analysis, it can be seen that the problem of concrete deterioration is an important one, despite the fact that the predominating performance of both pavements and structures is good. It is likewise of interest to note that a great many organizations are interested in the problem and that much new data are being accumulated each year toward the final solution of the problem.

Reasons for Concrete Deterioration

Concrete, as a construction material may be exposed to any or all of the following weathering or deteriorating actions: (a) alternate freezing and thawing, (b) wetting and drying, (c) heating and cooling, (d) deposition of salts by percolating water, (e) solution of some of the constituents of the concrete by water or acids, and (f) other detrimental chemical reactions, such as that which occurs between certain siliceous aggregates and alkali in the cement.

A brief study of the conditions which contribute to poor durability of concrete, and of the effects of the various exposure conditions, indicates that water is the greatest factor in the destruction of concrete by weathering actions. Water is either necessary for, or increases the severity of, practically every weathering action to which concrete is subjected.

Observation of concrete structures in the field shows that a wide range in resistance to weathering has been obtained in concrete construction. Under the same or similar exposure conditions, some concrete is in good condition after many years while other structures deteriorate rapidly. In many instances, highly variable performance is found in different parts of the same structure. The accompanying illustrations show deterioration of concrete in both structures and pavements.

Workmanship in Construction

Poor workmanship in construction can invalidate many of the efforts made to secure durable concrete by careful design of the mix and the structure. Complete specifications for mixing, placing, and curing of the concrete are usually prepared for all large projects and are frequently made a part of the standard specifications of organizations to be followed on all jobs, large or small. However, in far too many cases, both the quantity and quality of inspection are inadequate to secure proper adherence to the well-known and stipulated requirements for proper processing of the concrete.

To obtain concrete of maximum durability (for constant conditions of exposure, quality of materials and design of mix and structure), proper construction procedures would include: (a) accurate measurement of materials to insure uniformity of the concrete, (b) adequate mixing to distribute the materials uniformly throughout the concrete mass, (c) transportation and distribution methods that avoid segregation—in other words, don't undo the work of the mixer, (d) proper placing and finishing to insure complete filling of the forms without segregation or water gain and laitance, and (e) proper moist curing for an adequate time at temperatures well above freezing. Failure to use such procedures may result in non-uniform, segregated and honeycombed concrete or concrete porous and weak in places from laitance and water gain. Either condition provides greater facilities for the ingress of water with the accompanying danger of more severe weathering action. Curing is very important since moisture is necessary for hydration of the cement and the strength gain of the concrete. Freezing during the curing period is very detrimental, and too rapid drying out of the concrete tends to result in increased porosity.

In reinforced concrete structures, the placement of the reinforcing steel is a durability factor that perhaps should be included under both the design and workmanship problems. If the steel is covered by concrete either of poor quality or of insufficient thickness water will find ready access to the metal. The corrosion of the steel that takes place under these conditions (particularly severe when alternate wetting and drying is involved) results in large volume increases that crack and destroy the surrounding concrete. Examples of deterioration from this cause are relatively common.

Quality of Materials

The factors in concrete deterioration discussed in the preceding sections have long been recognized, and with care in design and construction are subject to control. In general, they contribute to increased opportunity for absorption of water and to increased severity of weathering exposure. The effect of the quality of the materials is somewhat different, in that the basic durability characteristics of the concrete are determined by the materials used. On the average construction job at the present time, the quality or durability of the materials is probably less subject to control than the design and workmanship factors. Although the durability of the concrete, as determined by the materials used, can frequently be modified somewhat by proper design and construction procedures, there are undoubtedly many cases in which good durability cannot be obtained regardless of the care used in controlling the design and construction. This thought might be briefly stated as follows: Poor design and workmanship may decrease the durability of potentially good concrete made with sound materials, but the best of design and construction practices will not necessarily insure good durability of concrete made with unsound or inferior materials.

During the past two decades, the problems of the quality of concrete materials (particularly aggregates) have been given a great deal of attention. With the discovery

Complete disintegration of pavement slab caused by using a coarse aggregate with poor freeze and thaw durability characteristics. Pavement at bridge and beyond is in much better condition due to the use of a different source of coarse aggregate which was more durable.

important: (a) failure to provide for porous backfill, (b) failure to provide for weep-holes or other methods of drainage, properly placed, and (c) omission of adequate waterproofing between embankment sections and abutments or wing walls. In addition to these factors in design that can affect the durability of the concrete, there are, no doubt, many others that deserve consideration. For example, thin sections tend to become saturated more readily than thicker sections of concrete and may be more susceptible to deterioration from freezing and thawing. Moisture changes and temperature variations may also affect them more severely. Under adverse conditions durability might often be improved by the use of thicker concrete sections, even though the greater thickness is not necessary from the standpoint of structural strength at the time of construction.

The nature of the concrete mix itself determines, to a large extent, whether the resulting concrete is durable, or weak, porous and readily susceptible to attack by water and weathering agencies. Poor gradation of the aggregates (including excessive fines), improper cement content, failure to employ proper admixtures when their use is indicated as beneficial, and the use of either too little or too much water for proper consistency and strength are all conditions that tend to produce porous, weak, inferior concrete that is likely to be more susceptible to deterioration than would a well-designed mix employing essentially the same materials.

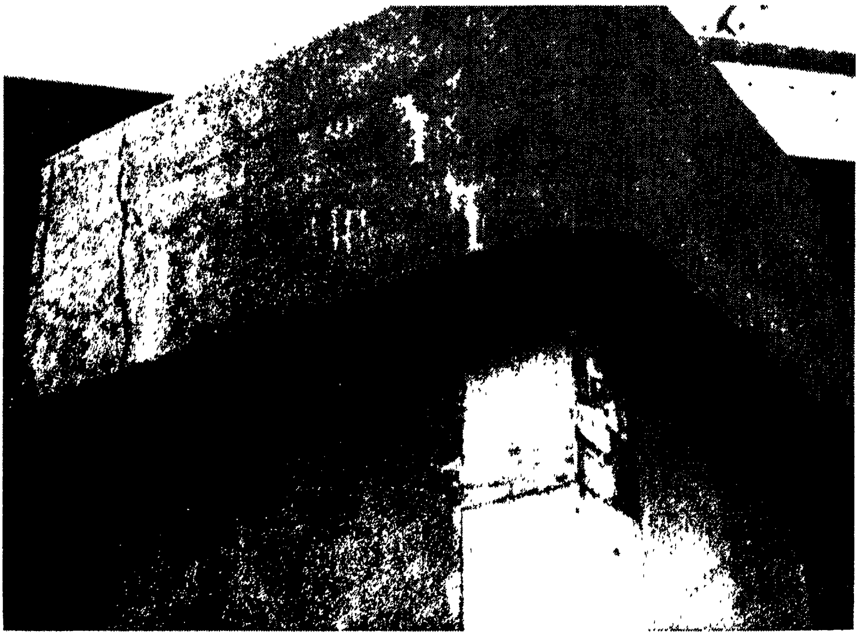
Deterioration of a wing wall caused by deleterious coarse aggregate which has become saturated by moisture from the earth fill. Dark areas indicate moisture that has seeped through the concrete.

of new problems (at least previously unrecognized) has come the realization that standard methods of test are inadequate for determination of the quality of the materials. Consequently, a huge amount of research work has been carried on by many organizations in recent years. The work done to date indicates clearly the need for new specifications and new methods of test for the quality of materials.

Cement is quite variable in physical and chemical characteristics, and in the past some difficulty has been encountered through the use of unsound cement. Present day cements, however, are generally sound; and, although trouble is possible from this material (i. e., alkali-aggregate deterioration in which the cement alkalies are the controlling factor), the evidence is limited that cement is a variable in the durability of concrete. Some variations in durability are undoubtedly due to the cements; but, except for the alkali-aggregate reaction, these effects will usually be obscured by the effects of a deleterious aggregate. Since the aggregate is approximately 75 percent or more of the volume of the concrete, it is readily apparent that their quality is a major factor in determining concrete durability. This discussion will, therefore, be chiefly confined to the effects of the aggregates on durability.

Alkali-aggregate reaction.—The problem of deterioration of concrete caused by a chemical reaction between certain types of aggregates and the alkalies in the cement was described by Stanton[8] in 1940. Other reports of poor durability from this cause soon appeared in the literature. Extensive research programs were initiated by many agencies to determine the mechanism of reaction, to identify the reactive materials, and to deter-

Deterioration along the top of a wing wall caused by deleterious coarse aggregate that was used in the concrete which has been attacked by two of the agents of weathering, i.e., wetting and drying, and freezing and thawing.



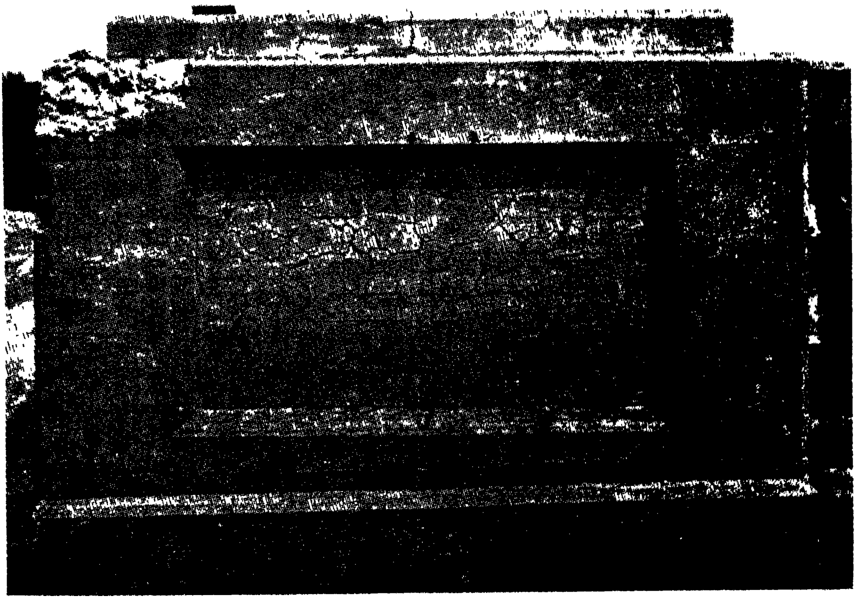
Disintegration of pier cap in Wyoming caused by alkali-aggregate reaction.
(Courtesy Dr. H. S. Sweet, University of Wyoming.)

The failures are caused by freezing of the aggregate when a high percentage of the voids are filled with water, so that insufficient air voids remain to allow space for the expansion that takes place when the water changes to ice. The absorption and pore or void characteristics of the materials are, therefore, controlling factors in the durability.

The problem of aggregates that have poor resistance to this type of weathering appears to be particularly important in the Midwest. The great amount of research work done to date shows clearly that the usual aggregate tests are inadequate and that new specification tests are needed if use of inferior coarse aggregates is to be avoided. In cases where it is economically infeasible to obtain high quality aggregates, air entrainment, drying of the material before use, and drainage to prevent subsequent saturation can be used to improve the concrete durability.

While the foregoing discussion is limited to coarse aggregates, some evidence exists to show that deterioration may be caused by unsound fine aggregates. Pavement performance surveys in New York and Pennsylvania indicate an influence of the sands used. Apparently the inferior sands, since the particles are small and closely spaced, exhibit their effect by progressive surface disintegration and weakening of the bond of the mortar to coarse aggregate. Water, of course, is again essential for deterioration. The problem of the fine aggregates is of lesser importance than that of the coarse aggregates, as shown by recent studies that indicate that sands affect the durability only in concrete with low air contents, and under all conditions have a much smaller effect than deleterious coarse aggregate.

Quality of Materials Related to Wetting and Drying.—The primary work on effects of alternate wetting and drying of concrete has been with sand-gravel aggregates, particularly those in Kansas and Nebraska. It was found that alternate wetting and drying



Deterioration caused by the use of an argilaceous limestone coarse aggregate in the concrete.

mine, if possible, corrective measures. Reports of the progress made in this research have been published at frequent intervals.[7, 9, 10, 11, 12, 13, 14] Although the investigators are not in complete agreement as to the precise mechanism of the reaction, the basic cause of the deterioration is a chemical reaction which takes place between the alkalies (NaOH and KOH) in the cement and certain siliceous materials in the aggregate (chiefly opal and some of the volcanic glasses). The reaction is accompanied by a volume increase which causes expansion and cracking of the concrete.

Mielenz and Witte[15] summarize and give the procedures for several test techniques for evaluation of the alkali-reactivity of aggregates. These include: (a) petrographic examination, (b) a chemical test, (c) mortar bar expansion test, (d) wetting and drying test of concrete specimens, and (e) examination of field structures in which the aggregate has been used. Water is vital to the reaction; either continuous moist storage or alternate wetting and drying is used to accelerate the reaction for laboratory testing.

Corrective measures used where reactive aggregates cannot be economically avoided have included limitation of the alkali content of the cement and addition of finely pulverized siliceous materials (usually pozzolanic in nature) to the mixes. Hanna[16] has suggested that surface waterproofing may be useful in decreasing the severity of the reaction under some conditions.

Quality of Materials Related to Freezing and Thawing.—The resistance of concrete to freezing and thawing and the influence of the aggregates upon the durability have long been a subject of investigation. Some of the early work was reported by Scholer[17] in 1928. Concrete failures caused by aggregates having poor resistance to freezing and thawing may occur as map-cracking or D-lines associated with general distintegration and blowups in pavements or as progressive scaling of the surface. Unsound cherts and some other materials often cause unsightly surface pitting and pop-outs.

straight linseed oil paint. Other less durable primers were pigmented phenolic varnishes, resins derived from rubber, pigmented lacquer primer, clear bakelite lacquer sealer, and alkyd resin emulsion.

In 1940, Copeland and Carlson[22] reported on the resistance to rain penetration of walls built of brick, tile, masonry units and concrete when painted with cement paints. The application of cement paint greatly reduced the amount of moisture penetration on all the wall types tested, except the cast-in-place concrete walls which showed no penetration and insignificant absorption either with or without paint.

In 1943, Fishburn and Parsons[23] reported on the effectiveness of approximately 30 waterproofing materials when applied to highly permeable unit-masonry walls of brick or concrete block. The walls were tested under conditions simulating exposure to wind-driven rain, both before and after they were subjected to artificial or outdoor weathering. The amount of moisture appearing on the back of the wall was used to determine comparative ratings of waterproofing ability. In these tests, only the cement–water paints were effective in preventing moisture from permeating through the walls and appearing as damp spots or beads on the unexposed surface. Other materials tested were emulsified resin and oil-base paints, and colorless surface waterproofings.

In 1947, Sentel[24] reported on the durability of paints for exterior masonry walls after outdoor exposure for three years. The paints were applied on concrete blocks, old and new bricks, and cast-in-place concrete wall specimens. "Considering the physical properties of the various structures and the number of coats of paint applied, cement–water paints as a class give best results with oil-base, resin-emulsion, and synthetic rubber-base paints, following in that order." In the appendix to this report, there is a graph which shows the ratings of some of the same specimens after six years' outdoor exposure. When considering concrete walls only, the durability ratings of the paints is just the reverse of that given for the three-year exposure tests, with rubber-base paints first with a rating of fair, and cement–water paints last with a rating midway between fair and poor.

In reviewing these and many other references to waterproofing concrete structures, it is apparent that two methods of waterproofing are practiced, depending upon whether or not the water entering the structure can be effectively sealed off. These two methods may be called permeable and impermeable waterproofing.

Permeable Waterproofing

In many instances, the application of a surface waterproofer, known to be completely waterproof, is unwise and to be avoided. Retaining walls, abutments, wing walls, or any part of a structure which has a fill behind it, is subject to permeation of moisture through the concrete from the fill. If this moisture appears on the surface, it must be allowed to permeate through any coating and evaporate. If the coating is impermeable, the moisture will be trapped where it will accumulate to form ice during freezing weather and will push the impermeable coating off the concrete surface. Undoubtedly, such a condition causes even more damage than if the surface had not been coated at all. For such surfaces, exposed to severe weathering, the application of a so-called permeable waterproofer will probably slow the rate of concrete deterioration, but it is no assurance that the structure will remain sound and serviceable for an indefinite length of time. The entrance of water from the fill side of the structure must be effectively sealed off to assure the integrity of the concrete.

For structures where moisture comes through the surface in such a volume that it is free-flowing, the area surrounding the leakage should be chipped out to sound concrete and then grouted. A hole should be drilled at the center of flow to concentrate

of the concrete duplicated the field deterioration of concrete in which the same aggregate had been used. Subsequent work, however, has shown that many of these aggregates are reactive with the cement and that alternate wetting and drying may accelerate the alkali–aggregate reaction. The influence of the volume change stresses from wetting and drying are, therefore, difficult to evaluate. It is possible that the major part of the deterioration is due to alkali-aggregate or some other cement-aggregate reaction.

Thermal Disruption.—In some cases, disruption of concrete has been attributed to the stresses set up by temperature changes alone when the aggregate and mortar have markedly different coefficient of expansion. Although some writers attribute a major role in concrete durability to this factor, it is believed that work on the problem to date is insufficient to definitely evaluate its effects and importance.

It is worthy of note, however, that concrete can be destroyed by rapid temperature changes (thermal shock), and that different rates of deterioratian are obtained when different aggregates are used. Water is apparently a significant factor in this deterioration, since specimens subjected to thermal shock while continuously wet (immersed in water) deteriorated very rapidly. On the other hand, similar temperature changes had little effect on dry specimens.

Waterproofing Concrete

The subject of waterproofing materials and techniques for concrete structures has been discussed by many writers since the turn of the century. More recently, Jumper,[18] in 1932, reported results of tests on 51 surface waterproofing materials, in which he immersed painted specimens in water and weighed them at frequent intervals over a period of a year. He concluded that "the most efficient coatings tested were some of the asphalt emulsions and bituminous solutions." The most efficient of the transparent coatings tested were linseed oil, China wood oil, and varnish.

In 1933, Anderegg[19] concluded, from information received from paint manufacturers and users, that concrete free from moisture ingress from behind can be coated satisfactorily with a paint having a high degree of impermeability. On the other hand, concrete which is subject to moisture ingress from behind should be coated with a paint which will allow the moisture to permeate through the surface coating and evaporate. "If moisture has a chance to escape through the surface paint, the film will not be pushed off as a whole by preferential wetting."

In 1934, Washa[20] reported the results of permeability tests on 9½-in. by 6-in. concrete cylinders coated with 18 different materials. The paint coatings were given efficiency ratings based on the reduction of water flow through the specimens at 40 psi. pressure for 50 hours before and after painting. The most efficient materials were 1:1 cement grout, Minwax, and a 1:2 cement grout, which were 88, 74, and 72 percent efficient, respectively. However, it was pointed out that reducing the moist curing period from 7 days to zero days reduced the efficiency of 1:1 cement grout from 88 percent to 45 percent.

In 1939, Blackmore[21] reported a study of the durability of nine primers and nine finish coats applied to concrete blocks after three years of outdoor exposure at Cincinnati in a smoky industrial atmosphere. No cement–water paints were studied. The durability of the various paints was determined by visual inspection. Two of the primers and one finish coat showed outstanding durability as compared to the other materials tested. The two outstanding primers were a long-oil pigmented primer and a phenol-formaldehyde resin which was cooked into a varnish of medium oil length to which was added aluminum bronze in the proportions of two pounds to a gallon. The finishing coat which showed such good durability when used with the two primers above, was a

Testing and Evaluation

After the five-day curing period, the specimens were weighed and then immersed in water for a period of 72 hours. The specimens were weighed during this period after 6, 24, 48 and 72 hours of immersion to determine how effective the various waterproofing paints were in preventing water from entering the specimens.

The first weathering test was exposure of one 3-in. by 8-in. coated specimen face to 150 hours of carbon-arc light, utilizing National Carbon Company "Sunshine" carbon rods and Corex D filters. After this test, the specimens were again immersed for 72 hours to evaluate the effect on the waterproofing ability of the paints. An increase either in the rate of absorption or in the total amount of absorption from that observed in the first immersion test indicated the extent of damage caused to the surface coating by exposure to the carbon-arc light.

The specimens were then subjected to 50 cycles of freezing and thawing at —18 deg. F. and 130 deg. F., after which they were allowed to dry in the oven for 5 days and again immersed for 72 hours to evaluate the effect of the freezing and thawing.

This concluded the laboratory tests, and the specimens were taken to an outdoor exposure platform where they were left for 90 days. They were then brought back to the laboratory where the rate and amount of absorption was again determined by a 72-hour immersion test.

Preliminary Results

In the first 72-hour immersion test, 16 of the 65 waterproofers reduced the 72-hour absorption of specimens by 50 percent or more when compared to uncoated specimens. However, after subjecting the coated specimens to the laboratory weathering tests, only 5 of the 65 paints retained the same degree of waterproofing ability they had shown in the initial immersion tests. Of these five, one was an amber, penetrating liquid; one was a mastic; one was a cement paint; one was a concrete enamel; and the other was a white, paste-in-oil paint with a granular filler. Less waterproof materials tested included plastics; emulsions; clear, colorless penetrating products utilizing either volatile or water solvents; asphaltic products; and other products of the same type as the five which were more waterproof. As a group, the cement-base paints were more durable in the weathering tests, but no more waterproof than any of the other groups of paint. Additional tests are now being conducted on the 16 products which initially showed fair to good waterproofing ability.

None of the 65 commercial waterproofers were completely waterproof, but in an experimental series we found that 4 coats of zinc-paste-in-oil housepaint of a good quality was completely waterproof through all the tests. Nine specimens, weighing approximately 1000 grams each, did not change weight when coated with the housepaint and placed in 72-hour immersion tests before and after the weathering periods. Raw linseed oil applied at 160 deg. F. was almost as effective as the housepaint when applied in an equal number of coats. These two products would probably prove satisfactory where an impermeable waterproofer can be applied.

Choosing the Right Waterproofing Product

After the waterproofing ability of a paint has been established, there are other questions to be answered before a paint can be chosen wisely. The prospective buyer of bulk quantities of waterproofing paints should ask the following questions:

the seepage of water so the grouting procedure can be carried out undisturbed. This hole can be plugged with a special plugging cement after the grouting operation and waterproofing have been completed. A durable, cement-base paint should be applied on such a surface as the damp condition of the wall aids in curing the paint, which can be applied as soon as the grout has hardened. Such treatment is referred to as allowing concrete to "breathe." Cement grouts, 1:1 or 1:2, should not be overlooked as a possible waterproofer wherever cement-base materials are desirable; also, the American Concrete Institute has adopted as standard a specification for cement-base paints, in which the components and proportions of each are given.

Impermeable Waterproofing

Now consider the completely waterproof or impermeable waterproofer. Where should it be used? The answer is, it should be used wherever there is no likelihood of moisture entering the structure from any source other than the surface to be waterproofed, such as the outer face of building walls, piers and columns above grade, and hand rails and balusters.

In the arid regions of the West, the impermeable waterproofer may be useful on every type of structure where disintegration can be attributed to condensation, at night, of water vapor which enters the surface during the daytime. The condensation takes place because of the day vs. night temperature differential, which is as much as 70 deg. at times.

Testing Program

The purpose of this investigation was to determine the waterproofing and weathering characteristics of various waterproofing paints when subjected to laboratory and field weathering tests, and to determine, if possible, a type of waterproofing material that was consistently better than all others.

Sixty-five products, representing a wide range of basic types, were submitted for test.

Fabrication and Curing of Test Specimens

The concrete specimens for these tests were fabricated from ten duplicate mixes designed for a water-cement ratio of 0.5 by weight, with a cement factor of 1.5 bbl. per cu. yd. of concrete. The fabricated specimens were 1 in. by 3 in. by 8 in. in size, so they would fit the specimen rack in the carbon-arc weatherometer which was used in the weathering tests. The 1-in. dimension of the specimen limited the aggregate size to ⅜ in.

The specimens were cured in water for seven days, followed by seven days of curing in an oven in which the temperature was maintained at 90 deg. F. At the end of this curing period, the specimens were etched with a 10 percent solution of muriatic acid, flushed with water, and placed back in the oven to dry for 24 hours before the waterproofing paints were applied.

Coating of Specimens

Three specimens were coated with each waterproofing paint according to the manufacturers instructions, and were placed in the 90-deg. F. oven to dry to provide uniform curing conditions for every specimen. The specimens were left in the oven for five days after the final coat of paint had been applied. This procedure was varied for cement–base paints, which were placed in a moist room for the first two days of the five-day curing period, to allow the paints to cure properly, and then placed in the oven for the remaining three days.

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Chairman Mays: I am sure that we have all gained some knowledge from Professor Woods' report on the deterioration of concrete and its relationship with waterproofing materials.

Mr. President, this completes the report of Committee 29.

President Schwinn: We wish to thank Professor Woods for his very interesting account of the developments in the field of waterproofing being carried out under his direction. And thank you, Mr. Mays, for the report of your committee. The committee is now excused.

Discussion on Impact and Bridge Stresses

(For Report, see pp. 287 306)

(President F. S. Schwinn presiding)

Chairman J. P. Walton (Pennsylvania Railroad): During the past year, considerable progress has been made on the regular committee assignments, both in the field and the office, by the research staff of the AAR in its study of the static and dynamic effects in railroad structures, even though a considerable part of the time was spent in conducting tests for the individual railroads at their request and expense.

Field studies were started this past year on the static and dynamic stresses in reinforced concrete structures carrying diesel and steam locomotives at high speeds. The first structure tested consisted of a continuous four-span viaduct on the Grand Trunk

Q. What is the covering capacity in square feet per gallon?

A. Information at present from a few of the manufacturers indicates the covering capacities of various paints range from 10 sq. ft. per gal. to 600 sq. ft. per gal. This information will be supplemented by data obtained when some of the paints are used on test structures at a later date.

Q. Are special precautions necessary for safe storage?

A. Many of the paints have to be protected against freezing, while others contain a volatile solvent, or require a highly volatile thinner, and must be stored in safety containers to protect against fire hazard. Eighteen of the 65 paints studied in our laboratory were subject to freezing and 17 were inflammable. Adequate dry storage must be maintained for cement-base paints which are stored in powder form until ready for use.

Q. Can the paint be applied satisfactorily?

A. Most waterproofing paints, other than the cement-base type, cannot be applied to new construction or where recent grouting and patching has been done. Keeping a cement-base paint coat wet for the time specified by the manufacturer is an absolute necessity to insure good waterproofing efficiency and maximum durability. Experienced supervision and adequate preparation for applying a cement-base paint, and keeping it moist until it has cured properly, are very important to its satisfactory application.

Some of the paints, especially the plastic transparent coatings, dry so rapidly that they are difficult to apply except when thinned with a special solvent obtainable only from the manufacturer. Some of the paints cause severe headaches when used in areas with poor ventilation, and others are practically impossible to remove from concrete surfaces where they are not wanted.

The answers to these questions are based on the experience of the authors in handling the 65 waterproofing materials which were included in the tests at Purdue, and it is hoped that they may prove helpful in those instances where a choice must be made between materials of comparable waterproofing ability but of different basic types.

Summary—Waterproofing

In summary, results of laboratory tests show a wide range of performance is to be expected between various waterproofing products. It follows that a product, with which the buyer is unfamiliar, should first be subjected to laboratory tests or, better still, be observed in the field where exposure conditions are as nearly as possible like those at the structures to be coated. In making field observations, it must be borne in mind that a paint giving good service on a building wall, which remains dry on the inside, is no assurance that the same paint will prevent deterioration of a retaining wall or an abutment where the principal source of moisture in many cases is from the fill behind the structure.

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[5] Jackson, F. H., "Disintegration of Bridge Concrete in the West", Public Roads, Vol. 24, No. 4, April–May–June 1945, pp. 98–111.

[6] Tremper, B., "Evidence in Washington of Deterioration of Concrete Through Reactions between Aggregates and High-Alkali Cements", Journal, American Concrete Institute, June 1941; Proceedings, Vol. 37, p. 673,

very little data were obtained on the dynamic effects. However, the results pertaining to the distribution of the load to the four arches, and the interaction of the envelopes and staves, will be of general interest to railroad bridge engineers. The data secured during the tests on this bridge were analyzed by the structural staff of the AAR and a summary of the data will be presented in a later report.

The Elgin, Joliet & Eastern has a 246-ft. 6-in. double-track, through-truss draw span across the Calumet river on its line into the Carnegie–Illinois Steel Company plant in South Chicago, Ill., carrying fairly heavy traffic. The bridge is subjected to the smoke and fumes of the steel mills and the truss and floor members have lost considerable section due to this corrosive action. Strains were measured in the main members and floor system under two double-headed test trains and the data were analyzed by members of the bridge department of the railroad, along the general lines followed by the AAR, to determine the carrying capacity of the bridge in its present condition. The results of the tests will only be of general interest to railroad bridge engineers as the speeds were not greater than 20 mph., so that only a summary of the test data will be presented in a future report.

The failure of the counterweight trusses of the bascule bridge on the Great Northern in 1948 focused attention on this type of structure. Consequently, the research staff was requested by two railroads to secure strain gage readings on similar structures. Stresses of considerable magnitude were recorded in the counterweight truss members, and a report of these readings has been prepared for distribution. The principal cause of these high stresses is a rotation of the joint as the bridge is opened, which produces high secondary effects.

Possibly the most original work done so far by the structural staff was for the Corps of Engineers at the request of the New Orleans, Texas & Mexico, and consisted of extensive pile tests in the swamp lands of Southern Louisiana. Loading tests to failure, or near failure, were conducted on long timbers, piles, and on hollow-steel friction and end-bearing piles. Ten individual piles, as well as three groups of nine piles each, were tested by loading them with large concrete blocks.

Strain gages were placed longitudinally along the inside of the steel piles at 5-ft. intervals and readings were taken during the driving, as well as during the loading of the piles.

Analysis of the data secured on these pile tests has shown how the load, both static and dynamic, applied to the top of the pile, is finally distibuted to the soil along the length of the pile. The data also indicate how the load on a group of piles is distributed between the individual piles of the group.

The report on these pile tests is completed and is awaiting the approval of the Army Engineers for release before publication in an AREA Bulletin.

In addition to work on the regular assigned projects of the committee, the structural staff takes on active part in the work being done by the Research Council on Riveted and Bolted Structural Joints, the Column Research Council, the American Society of Civil Engineers, and the American Society for Testing Materials. The staff is also usually represented at the various committee meetings of the AREA dealing with structural problems, and assists in every possible manner in the research work of the committee.

The large increase in the cost of structural timbers in recent years has made it necessary for bridge engineers to review the design stresses in such members, especially since about 50 percent of all bridge mileage in this country consists of timber trestles.

Recent laboratory tests at the Forest Products Laboratory on small specimens have indicated that timber will fail in fatigue if subjected to a sufficient number of cycles of

Western, at Flint, Mich. Stresses were measured in both the concrete and reinforcing steel at the center of the 39-ft. spans and over the supports under both diesel and steam locomotives at all speeds up to about 60 mph. Impact values of considerable magnitude were obtained, but the maximum recorded stresses were considerably lower than those calculated.

The second structure tested consisted of a precast reinforced concrete slab supported by reinforced concrete cap and piles on the Chicago & North Western. Here again, the maximum recorded stresses in both the concrete and the steel were quite low, even though impact values of considerable magnitude were recorded. It appears that the design loads are not large enough to crack the concrete on the tension side, so that the structure is not following the usual assumptions made by the designer. The result is a much larger factor of safety than we normally assume.

The analysis of the data secured on these two concrete structures is nearing completion and a report covering these tests will be presented this year.

The office force of the AAR recently completed a report of tests on three medium-length girder spans on the Chicago & North Western. This report, which will be published this year, summarizes the results obtained under 100 diesel locomotives and 386 steam locomotives on the three spans. These results are of particular interest to railway bridge engineers as they include considerable data on the static and dynamic stresses in the girder web plates at the ends of the spans, as well as at the quarter points. The maximum recorded stresses in the flanges at the center of the span are well below the calculated values, but the recorded maximum stresses in the web plates exceed those calculated by a considerable amount. However, the assumption made in the design of web plates has always resulted in low allowable stresses.

In addition to the preparation of the report on the Chicago & North Western girder spans, the office force of the AAR has completed the analysis of nine other girder spans of various lengths as part of the assignment on this type of structure, and work will soon start on the preparation of tables and diagrams for a report on these bridges.

As previously mentioned, a considerable part of the time of the structural staff has been spent in making tests on structures for individual railroads at their request and expense. During the past 10 years about 40 percent of the time of one field party of three men has been doing this work for individual railroads. However, a considerable amount of this data is being used in progressing the committee's assignments, and all of the work adds greatly to the knowledge of railroad structures.

Early last year the AAR was asked by the Texas & Pacific to determine the static and dynamic stresses in two of its short truss spans, about 125 ft. in length, where some trouble had been encountered with the lower chord members near the bearing shoes, as well as with the floorbeam hangers. Tests were conducted under the heaviest steam power on that road at speeds ranging from crawl speed to over 60 mph., and the data were analyzed by the bridge department of the railroad along the general lines followed by the AAR. The data secured on these bridges will be of great value as part of the assignment on steel truss spans.

Interesting tests were made on several chord and web members of one of the 520-ft. arch spans of the Eads bridge across the Mississippi river at St. Louis, at the request of the Terminal Railroad of St. Louis. This structure was completed in 1874 and carries both highway and double-track railroad traffic. The chrome steel members in this bridge have a yield point of 55,000 psi., and each chord member consists of six longitudinal staves held together by a longitudinal steel envelope. The tests were conducted with either one or both tracks loaded with double-headed diesel locomotives followed by heavily loaded cars, but since speeds of only about 16 mph. were attained,

Discussion on Masonry

(For Report, see pp. 363–412)

(President F. S. Schwinn presiding)

Chairman C. B. Porter (Chesapeake & Ohio): Before presenting the report of the Masonry committee, I want to express to the Association our great loss and regret in the passing of Karl R. Beck, chief masonry inspector of the Illinois Central and a member of this committee, and William Morrison Ray, retired senior assistant engineer of the Baltimore & Ohio, and a member of the Committee on Masonry for 19 years. Mr. Beck died April 7, 1949, and Mr. Ray passed away November 5, 1949. Biographical sketches have been prepared and are recorded in the report of the committee.

Assignment 6—Methods of Repairing Masonry, Including Internal Pressure Grouting, R. W. Gilmore (Baltimore & Ohio), subcommittee chairman.

Mr. Gilmore: There are three general classes of concrete repairs; namely, hand patching, internal pressure grouting and shotcrete. Your committee felt that the subjects could best be handled by preparing two separate specifications. The specifications for shotcrete will be presented at a later date.

Tentative specifications for repairing and solidifying masonry structures were submitted in 1948. Your committee now offers revised specifications for publication in the Manual to replace the material on pages 8–141 to 8–142, inclusive.

There are two corrections which will be noted in the report.

Repairing and Solidifying Masonry Structures

A. General

In the seventh line from the bottom of page 365, starting, "And bonding, waterproofing—", change the "and" to "any."

B. Surface Repair

At the top of page 367, after the first table, add to the line reading, "Any anchor failing to support such load shall be reset," the words, "and tested." It should now read, "Any anchor failing to support such load shall be reset and tested."

At the top of page 368, the first paragraph, substitute the following:

"A two-way system of ¼-in. diameter reinforcing bars shall be provided in the last layer of new concrete on vertical and suspended surfaces. These bars should be securely wired to anchors and the last layer of mesh shall be secured by wiring to the bars. Reinforcement, including mesh, shall be continuous, except over expansion joints."

Mr. Chairman, I move that these specifications be approved for publication in the Manual.

(Vice-President H. S. Loeffler assumed the chair.)

(The motion was seconded, put to a vote and carried.)

Assignment 7—Methods for Improving the Quality of Concrete and Mortars, M. S. Norris (Baltimore & Ohio), subcommittee chairman. In the absence of Mr. Norris, the report was presented by A. N. Laird (Grand Trunk Western).

Mr. Laird: The report deals with the influence of aggregate characteristics on the proportioning of concrete. There are two typographical errors in the report. First, on page 373, the first paragraph, the twelfth line should be deleted and in place of it, substitute, "the absolute volume of coarse aggregate in a unit volume of dry rodded coarse aggregate."

stress. Since the timber trestles carrying railroad loading are subjected to a large number of cycles of stress, it was considered advisable to investigate this feature. Consequently, arrangements have been completed with the Forest Products Laboratory and Purdue University to conduct repeated bending tests on full size pine and fir stringers, and this program is now underway on new stringers.

The arrangements with the laboratories also include the testing of full size stringers removed from trestles, which have been in service for 30 or 40 years, to determine the useful life of such members. The information secured from these tests on old stringers should be of extreme value to bridge engineers as a guide in renewing timber trestles.

The structural staff of the AAR expects to complete the field tests on girder spans this summer, so that a final report on this assignment can be presented. Work will continue on the other assignments, especially the study of the distribution of live load in transverse floors and longitudinal stringers, the study of concrete structures, and the study of stresses and impacts in timber stringer bridges. In addition to this committee work, the research staff will undoubtedly spend some time in conducting tests for individual railroads, although no requests have been received to date.

President Schwinn: Thank you, Mr. Walton.

K. L. DeBlois (New York Central): In regard to the bridge failure, what was the type of span and when was it built?

Mr. Walton: I don't know when it was built. It is a trunnion span.

Vice-President Loeffler: The bridge referred to is a double-track structure located at Inner Bay, a short distance north of Seattle, Wash. It was built in 1914. The bridge was put out of service as the result of the fatigue failure of a member in the counterweight truss, when the bridge was in the open position. The bridge was supported by falsework in the open position while the failed member was repaired.

E. A. Johnson (Illinois Central): In connection with the tests made on the piling in Louisiana, were these tests made on batter piles as well as plumb piles and if so, was there any difference in the load carrying capacities?

Mr. Walton: I haven't seen the results of the tests yet. They told me they haven't been released, but that they expect them to be released any day.

Mr. Johnson: How did the load-carrying capacity of the piles that were tested compare with the theoretical capacity as determined from the normal pile-driving formula?

Mr. Walton: They have the driving data, but I don't know how they compare.

W. R. Wilson (Atchison, Topeka & Santa Fe): In regard to the test on concrete slabs, you stated that it appeared that the design loads are very low and the slabs are not following the usual assumptions made by the designer.

Is the committee going ahead to see if we could be wrong in our design assumptions, and is it going to try to find new methods of approach on this?

Mr. Walton: The committee will have to investigate and recommend what should be done. We haven't done that yet.

F. E. Schneider (Atchison, Topeka & Santa Fe): On the testing of old stringers, how are these old stringers to be tested, and how are you going to determine the remaining useful life of these stringers?

Mr. Walton: We will have to wait until we get the data on the tests and results before we can answer your questions.

President Schwinn: Thank you, Mr. Walton. Your committee has done an exceptionally fine job in the past year and we look forward to as fine a report next year. The committee is excused.

has a much greater supporting power than a large volume of the same fluid. Therefore, the thickness of the paste coating the aggregate particles should be kept at the minimum.

The art of making good concrete need not be made so complex that only the so-called experts will be able to obtain satisfactory results. While it is true that scientific proportioning has replaced rule-of-thumb methods, the basic principles involved in combining the essential ingredients of concrete remain the same. Aggregates, which are the most variable of the essential ingredients, affect proportioning more than is generally realized and deserve more attention than is given them.

The geometrical characteristics of aggregate particles, taken both individually and collectively, should receive serious consideration only to the extent of their effect on the quantity of water-cement ratio paste required to provide the desired consistency. The characteristics of the aggregates being considered for use in a concrete mixture must be carefully examined, whether the method of mix design is empirical or theoretical. Since aggregates from the same source may vary from day to day, constant inspection and periodic testing must follow the original sampling and examination of the material, if satisfactory concrete is to result.

This report will not provide the answers to all proportioning problems. However, the fundamental principles of proportioning presented therein will prove useful to the engineer engaged in the design of concrete mixtures.

Vice-President Loeffler: Thank you, Mr. Laird, for this very informative report.

Assignment 8—Specifications for the Construction and Maintenance of Masonry Structures, was presented by W. R. Wilson (Atchison, Topeka & Santa Fe), subcommittee chairman, who commented on a simplified guide offered by the committee covering the principles of concrete manufacture, intended primarily for the use of supervisors or young designers who desire to learn more about the fundamentals of concrete mix and design.

Mr. Wilson: Those who were in the army during the last war, were, I believe, much surprised at the jobs assigned to army officers. They were quite different from the popular concept of their duties. An army officer, both in wartime and peacetime, spends at least a third of his time going to school or in teaching. Also, the troops spend much of their time going to school. The final test for both teachers and the students was their effectiveness in battle, and our troops were effective.

You may be wondering why I am talking about the army when giving a report on masonry. The railroad supervisory officer on the division, occupies a place very similar to that of an army officer. There is discipline, and although it is not as iron-clad, it is just as rigid on the railroad as in the army. The name of the basic railway operating unit—division—is the same as the basic combat unit in the army. Operating officers—engineers, general foremen and bridge and building department supervisors, should be like army officers. They should be teachers and should spend a lot of their time teaching the men working under them. The test for both the pupils and the operating officers is how the structures they build stand up. The younger bridge and building foremen and supervisors, and the young rodmen just out of college who are sent out as inspectors on small concrete jobs, all want to improve their knowledge. They are ambitious and want to get ahead.

When one starts to read some of the existing literature on the design, mix and reinforcement of concrete, he begins to run into terms such as finest modules, absolute volume, voids, etc., and unless very ambitious he will soon give it up. It is difficult and takes time to look up the definition of each word that one doesn't understand. With the idea of helping such people, your committee has prepared and published a guide to the

Then, on page 376, in the paragraph headed "Unit Weight," in the third line, the period should be a comma for clarity, and the second word in the line, "a," should be "as."

I would like to highlight this report briefly by emphasizing certain points.

Good concrete is a prime objective of all construction men, and proper care in the selection and use of aggregates will contribute much toward the achievement of that goal. This report was written to bring to your attention those physical characteristics of aggregates which have such an important influence on proportioning.

The water-cement ratio method of designing proportions for concrete mixtures has become universally established during the past 30 years. With the use of that method, the aggregate requiring the least water will also require the minimum of cement—which is the most expensive ingredient in concrete.

One important fact which should be kept in mind in the selection of aggregates is that the shape and size of the aggregate particles have a definite effect on the amount of water required to obtain the desired workability.

The shape of an aggregate particle is usually either worn smooth by water, or is sharp as a result of crushing. A rounded aggregate with uniform grading will contain less voids and, therefore, will require less cement paste than an angular aggregate of the same grading for the same workability. The excess of paste for angular particles may require as much as three additional gallons of water per cubic yard of concrete, and the corresponding increase in the quantity of cement required may result in a less economical mixture.

The principles of proportioning concrete, however, are the same regardless of the characteristics of the cement; and a mixture of the desired consistency may be obtained if the differences in the aggregate particle size and shape are taken into consideration.

It is interesting to note that, considering the importance of particle shape, there is no accepted standard test for determining that characteristic of aggregate. The engineer must depend on visual inspection.

The size of the coarse aggregate particle also has an important effect on the amount of cement required in a concrete mixture. An excess of any one size of aggregate particles will tend to cause segregation in the mixture and be uneconomical due to the high percentage of voids. A properly proportioned combination of aggregate particles contains all sizes between the smallest and the largest. Good workability with a low cement factor can only be obtained with a carefully graded aggregate. Find gradings, which require more water for workability, require more cement and are, therefore, not economical. There is marked economy in the quantity of cement required when the maximum size of aggregate is increased up to three inches. An increase from one-half inch to one and one-half inches can result in the saving of one sack of cement per cubic yard of concrete.

One of the fundamental and highly important principles in the proportioning of concrete for a desired consistency is that a film of mortar must exist around the coarse aggregate particles. Harshness occurs in a mixture when the amount of paste is not sufficient to prevent contact between the particles of coarse aggregate. Paste in excess of that required to coat the aggregate has no value, and affects the economy of the mixture.

In a plastic concrete mixture, the cement and aggregate particles are virtually suspended in water, even though the specific gravity of the solid particles is greater than that of the fluid itself. In order to form a suspension, each particle of aggregate must be separated from all neighboring particles by a continuous film. A thin film of any fluid

Vice President Loeffler: Mr. Wilson, your committee should be congratulated on the preparation of its excellent and useful report. I would like to call attention particularly to the arrangement of this report, the division into suitable chapters, the provision of subheadings, etc. Your report would be very useful for field use.

I think we should go a step further in connection with this report. This is a report which should be printed in pamphlet form so that it can be conveniently secured by the various railroads and distributed for use in the field. If the Masonry committee sees fit to make a recommendation of that kind, I am sure the matter would be considered seriously by the Board of Direction. Thank you very much.

Chairman Porter: Thank you, Mr. Wilson. So much has been said about concrete deterioration that we often ask what is being done about it. Much is being done, both in the laboratory and in the field.

Mr. G. H. Paris of the Portland Cement Association, and an associate member of the Committee on Masonry, will present a paper on concrete performance tests.

Concrete Performance

By G. H. Paris

Railroad Representative, Portland Cement Association

Let's consider for a moment our bridge and building foreman. How much is he worth to your railroad? During the 30 or 40 years that he works for it he probably constructs bridges, buildings and other structures worth several hundred thousand dollars. The quality of concrete going into those structures and the service you receive from them depend largely upon the foreman's ability. Yet, how much time do you invest in educating him in the fundamentals of quality concrete and its importance in the performance of these structures?

We must not only educate the men, but we must furnish them with the necessary equipment for controlling the manufacture of the concrete in the field, and also furnish specifications that represent the best practices. Your Masonry committee recognized the importance of educating the field forces in quality concrete construction and prepared the Guide to Water-Cement Ratio Method of Making Concrete, written especially to assist these forces in this important work. The "Guide" outlines the fundamentals of quality concrete and describes and discusses each step, starting from the selection of materials and continuing through to the finished product. I urge all of you supervisory officers to see that your men receive copies of the "Guide" and that someone explains its use to them.

Sometimes in our desire to economize in materials or save time on a project, we overlook certain construction techniques or compromise on the basic principles of making good concrete to the extent that we lower its quality. Yet, when the structure is completed, we expect it to perform just as well as a structure constructed according to the best practices. I'd like to show you a few examples of concrete specimens taken from an experimental project, which illustrate the effect of improper construction on concrete performance. I'd like to point out that all of these improper construction practices can be corrected in the field.

In 1940 the Portland Cement Association began a long-time study of the performance of cement and concrete with the cooperation of several state highway departments and other agencies. The investigation was activated by the desire of both consumers and

A

water–cement ratio method of making concrete. This has been about a four-year job. There is great need for this guide. We still hear people talking about poor concrete and the trouble they have getting their foremen to put in a water–cement ratio concrete.

The water-cement ratio theory was first introduced here in Chicago at Lewis Institute in 1918, by Professor Duff Abrams. That is 32 years ago, but we still consider it new and are still having difficulty in getting our men to make concrete according to that theory. So, it was also with that in mind that we prepared this guide, which consists of a summary of 19 clauses. The first one deals with the most important thing—the amount of water used and the control. Other clauses point out—if other tests cannot be made, the water should be drinkable; "be on the alert for changes in aggregates and handle them so as to avoid separation of the sizes," "take decent care of mixing equipment," and finally, "good concrete is a monument to you."

Chapter 1 covers Basic Principles. In that, italicized, we give the water-cement ratio strength law.

On the proportioning of concrete, the committee worked quite a while to get a suitable statement, in simple language, of what we are trying to accomplish when proportioning concrete.

We think that if we can get these things across to the foreman and the young inspector who has to design and mix for the smaller jobs, they will understand what they are trying to do. Notice, we don't talk about the finest modules or the absolute volume method. We just say that every particle has to fit in with some other particle and be glued together with the cement-water mixture.

Then in Chapter 2, Proportioning Concrete, we have given the table of suggested trial mixes that was presented last year as information. Your foreman might be a little disturbed by all these figures, but as any teacher does with a book, you should assign only certain portions of it at a time. The inspector or division engineer should extract just the portion that is needed. For instance, if he is using 3000-lb. concrete with a maximum of 1½ in. aggregate, he can give the foreman only that part of the table relative to the weight of the sand and the gravel, the amount of concrete, and the total weights. This is also given in volume.

The text then explains how the mix can be varied for different slumps by adding to or taking away from the coarse or the fine aggregate to get the slump desired. The slump test is explained. All of this is in simple language and occupies four pages.

Following this is Appendix A, which contains instructions to field men. This takes the AREA specifications for concrete structures, breaks them down by each section and gives the reader an explanation or pointers on their use. It is so set up that he does not have to have specifications with him to use the appendix.

There is also included a drawing showing the correct and incorrect handling of aggregates in storage and transit. It is very important to keep from segregating the aggregates and the pictures show simple methods of doing this.

There is another insert showing simple methods, and some more complex, of handling the mixed concrete to avoid separation in the concrete. There is one typographical error in paragraph 18. The committee knows that a lot of "mental" work goes into the design of concrete, but obviously in the sentence, "No mental supports or ties shall extend to the surface of the concrete," the word "mental" should be "metal."

The final portion of the guide includes definitions of the terms used. These definitions are not exactly dictionary definitions, but they define in plain language the accepted meaning as far as concrete work is concerned.

Your committee gives this guide to the Association, hoping that it will find widespread use, and that the quality of concrete will be improved thereby.

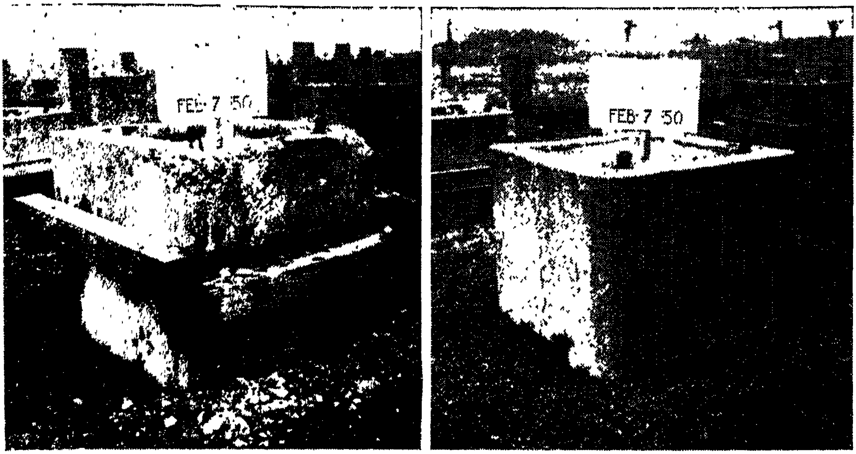


Fig. 1.

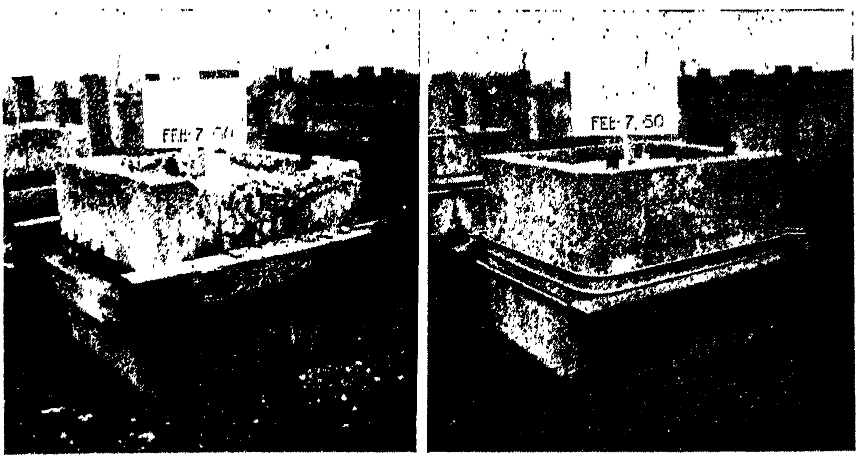


Fig. 2.

Over-wet mixes are responsible for much of the poor-quality concrete found in structures exposed to severe weathering. In Fig. 2 the box specimen at the left was made with concrete of 8-in. slump, and the other with concrete of 1½-in. slump. The same cement was used in both specimens, with the same aggregate and in the same proportions. In this case there was a short-time interval between the casting of the two test specimens, which may have had a slight effect on their relative performance. The importance of maintaining proper control of water for producing durable concrete is evident from the better appearance of the specimen on the right made with the low slump concrete. The minimum amount of water necessary for proper placeability of the fresh concrete is always more than is required for hydration of the cement. Water in excess of this minimum amount results in increased porosity and permeability of the

manufacturers of cement to improve the quality of concrete. The test program was laid out and its progress studied by an advisory committee composed of eight members outside the industry and four from it. The program includes test roads in three states—New York, Missouri and South Carolina; four pile installations—Cape Cod canal, Florida, Hudson river and California; walkway slabs on Florence Lake dam; parapet walls, Green Mountain dam; sulfate exposure tests at Sacramento, Calif., and experimental farms in Illinois and Georgia.

At the experimental farm in Illinois, concrete control specimens are exposed to natural weathering. The project includes more than 1000 specimens of three different types. One type of specimen is a slab 2 ft. 6 in. wide, 6 in. thick and 3 ft. 6 in. long, cast in place on the ground to simulate a concrete pavement. Another is a concrete box 2 ft. 6 in. square, cast in place and filled with sand and water. This type of specimen represents such structures as retaining walls, bridge abutments and ballast-deck bridges in direct contact with wet soil. The third type of specimen is an 8-in. square column, 5 ft. long, embedded 2 ft. in the ground. It represents structures such as bridge piers, foundations and walls partly exposed to weathering and partly buried in the ground. Six different mixes and two combinations of aggregate were used in the construction of the boxes and columns.

This long-time study enables engineers to examine concrete specimens under conditions of exposure comparable to the exposure of field structures, and to determine what properties of the concrete are responsible for the differences in their performance. Certain differences are already apparent in some of the box specimens. These demonstrate quite effectively the benefit of air-entrainment and, with certain reservations, the benefit of low slump vs. high slump, rich mixes vs. lean mixes, summer vs. late fall construction, and good quality vs. poor quality aggregate. There are also preliminary indications of the effects of certain construction techniques. All of these factors have a direct influence upon the durability of concrete, and again I want to emphasize the fact that all of these factors can be controlled in the field.

Box specimens for each of the 6 mixes and 2 aggregate combinations were made with 27 different cements, representing all 5 ASTM types. This wide range of variables offers an excellent opportunity for studying their effects on the performance of concrete. Although this project is intended primarily as a comparison of cement performance, the effect of factors, such as mix proportions, quality of aggregate, and construction practices, may be studied, provided proper consideration is given to the time of year in which the different specimens were cast.

The benefit of air-entrainment is strikingly obvious on inspection of the boxes. Fig. 1 shows two typical examples of boxes made with the same mix and same aggregates, and cast at the same time. The significant variable is that the specimen on the left was made with non-air-entraining cement, while the one on the right was made with cement ground from the same clinker, except that an air-entraining agent was added during grinding. The concrete mix used in their construction was too lean and too wet to produce durable concrete under severe exposure, yet was representative of many mixes actually used in the field. The cement content was 4½ sacks per cubic yard, and the concrete had an 8-in. slump. It is evident that the specimen made with air-entrained concrete is showing much greater durability than the one made without entrained air. This good performance, however, should not be interpreted as an excuse for the use of air-entrainment to compensate for materials of inferior quality, or for improper construction practices.

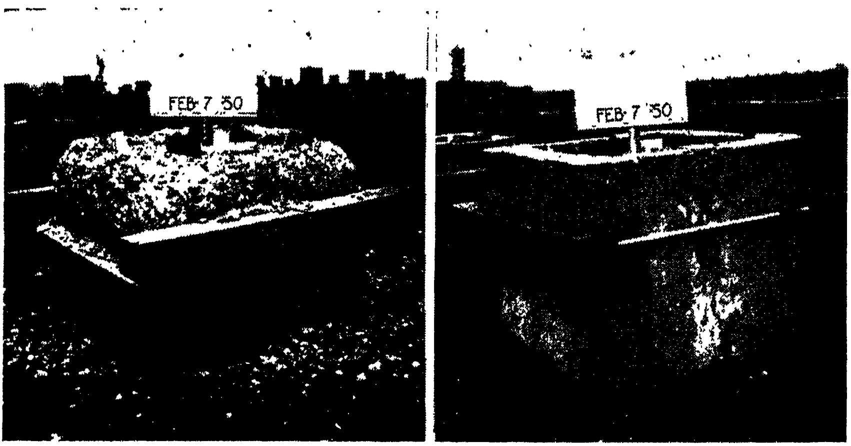


Fig. 5.

Fig. 6.

Consideration is seldom given to the effect of inadequate curing at proper temperature in cold weather construction on the durability of concrete to be exposed to severe weather conditions. Recommendations are available for cold-weather construction which will produce good quality concrete. Too often such recommendations are disregarded, in part at least, with a resulting depreciation in concrete performance. In Fig. 4 the box on the left was made in the late fall, whereas the box on the right was made the following spring. Mix proportions, materials and slump were the same in both cases. The benefit of long curing and seasoning at favorable temperatures before freezing weather started is obvious. It is important in winter construction that the concrete be properly protected and adequately cured to insure durability.

Many factors enter the proper selection of aggregates for durable concrete. Performance records of aggregates should be examined, and adequate tests made before using a particular aggregate. To illustrate the effect of aggregate of doubtful quality on concrete performance, specimens were made using a sand which had a poor performance record. The specimen on the left in Fig. 5 contains this sand, while the specimen on

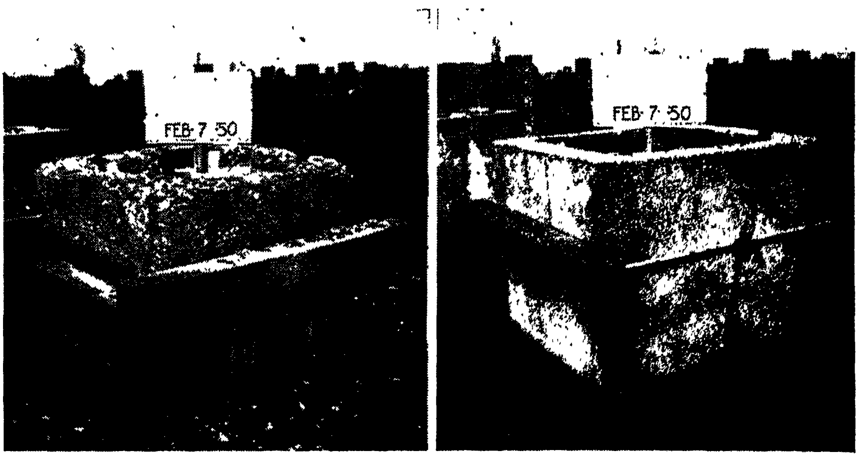


Fig. 3.

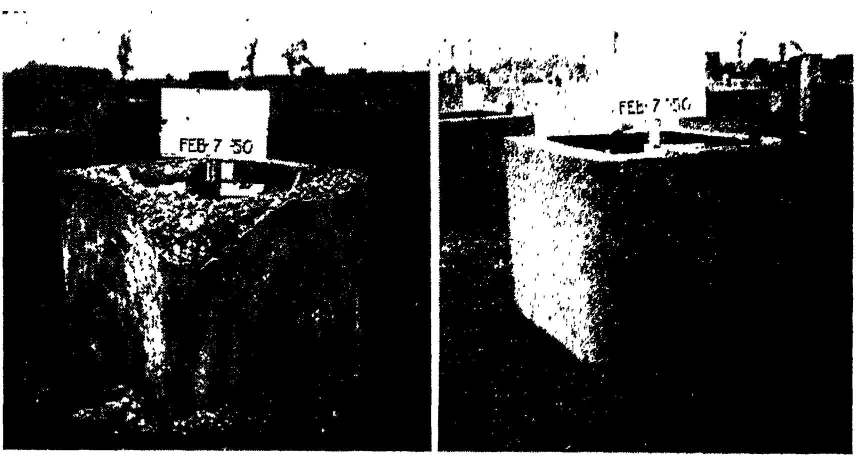


Fig. 4.

hardened concrete, and thus reduces durability. Obviously, it is good business to furnish field forces with proper equipment so that materials can be batched, mixed and placed correctly, and the resulting bad effects from improper construction practices thus avoided.

The effect of a rich vs. a lean mix is demonstrated in Fig. 3, which shows two boxes made with the same cement, aggregate and slump, but with concrete of different cement content. The specimen on the right was cast approximately two weeks earlier in the fall than the specimen on the left (see following paragraph). The specimen on the left was made with 4½ sacks of cement per cubic yard, while the one on the right was made with 6 sacks per cubic yard. It is evident that there is no economy in skimping on cement and sacrificing on durability.

Article 203 on pages 15-6 of the Manual, now has a figure that would give us an axle load of 90,000 lb. in two axles, spaced 7 ft. apart. This was a carry-over when the railroad loadings were first written for Cooper E 40 loading. It is now felt that with 72,000-lb. axles, an alternate loading of 90,000-lb. axles spaced seven feet apart is no longer necessary, and that, so far as the design of the structure is concerned, there are very few parts, if any, which would be affected by any alternate loading. For this reason we are asking that this figure be deleted.

Article 204, paragraph (a), page 15-7, is for the purpose of clarifying this article. The present article does not state whether the track is open or ballasted, and needs clarification.

Likewise, as to the load *P*, there has been some question as to how the load should be distributed. The present specification doesn't say. We have in a way made an arbitrary assumption. If you will make a few computations you will find that you will get practically the same results, whether you assume the load *P* as concentrated or uniformly.

In Article 206, Subparagraph (b) on page 15-8, we are proposing revision of the two definitions of the span length in the article on impact. No reference was made in the first definition as to what length should be used in applying the impact formula for transverse floorbeams without stringers, so we have inserted this length in the first definition. In the second definition, we had omitted reference to stringers. We had supposed that when we referred to beams, that people would understand that a stringer was a beam, but in the past year or so we have had questions from several people engaged in teaching, asking for clarification. Therefore, we have inserted the words, "supported stringer," to supplement the longitudinal beam in this definition.

Article 428, page 15-18, has been clarified as a result of the request of one of the steel fabricating companies. Of interest is the fact that for many years it has been understood that impact was to be included in the design of rivet pitch. However, our specifications as they now stand are none too clear on this point. It seems there have been a number of interpretations by different fabricating companies, and in order to standardize the design, this article has been revised. Also, this particular article did not give the distribution to be used for ballasted deck girders.

In Article 511, page 15-24, an editorial revision was made as a result of one of the railroads having difficulty with a small fabricating company which apparently did not understand that when the parts of riveted members were firmly drawn together with bolts, they should be in close contact. To clarify this we have inserted the words, "in close contact," so this difficulty may be prevented in the future.

Revision of Article 703, page 15-30, is necessary to tie in with revision of Article 801 previously made.

Likewise, in Article 801, on page 15-35, there is an editorial change to correct a typographical error.

On page 444, there is a revision to the Rules for Rating Existing Iron and Steel Bridges. This came up before the Association last year, and was presented as information, with the request that if there were to be any comments, they be sent to the committee chairman. Since we have received no comments, we are asking that this revision be adopted this year.

If you will examine page 444, you will see that in the presentation last year there were a number of typographical errors which were corrected on the floor, which are listed on page 444.

There is another typographical error in this material which I should like to correct at this time. In the second item on page 444, beginning, "On page 429, Article 107,

the right is made with an aggregate known to be of good quality. Cement content, slump and other conditions of test were the same, except that the specimen on the right was cast about three weeks earlier in the fall than the one on the left.

Much of the deterioration in field structures occurs at the tops of wing walls, retaining walls, parapets and at similar locations. Water gain and laitance accumulated during construction produce a weak porous concrete at the point of attack by weathering, which is largely responsible for the resulting deterioration. This effect is clearly seen in the foregoing illustrations. In all cases, the distinction is greatest at the top and becomes less as the distance from the top increases. Most difficulties from this segregation of materials in placing can be eliminated by overfilling the forms and allowing the concrete to stand for about an hour before it is struck off.

The benefit of this procedure in placing concrete is shown in Fig. 6. These specimens were identical, except as to time of placing and method of financing. The one on the left was cast early in the fall, while the one on the right was cast early the next spring. The specimen on the left was finished immediately after the concrete was placed, while the one on the right was finished as recommended above. While some improvement in performance of the concrete in the box on the right is due to better curing before winter set in, a large part is believed to be the result of the elimination of the weak and porous concrete at the top.

The factors affecting the performance of the test specimens shown in the illustrations are responsible for most of our poor quality concrete. All of these factors can be controlled in the field. This requires adequate specifications, proper materials and equipment, qualified supervision, and the support of field personnel by management officials.

Mr. Paris, we thank you for this very interesting paper. I also wish to take this opportunity to thank the members of the committee for the splendid cooperation they have given me during the past year.

Vice-President Loeffler: Thank you, Mr. Paris, for your very excellent paper, and thank you, Mr. Porter, for the fine report of your committee. You and your committee are now excused with the thanks of the Association.

Discussion on Iron and Steel Structures

(For Report, see pp. 441–540)

Vice-President Loeffler: Having at one time served on Committee 15, it gives me great pleasure to introduce this committee at this time. The chairman of this committee, who is assistant engineer of structures of the New York Central System, will present the report.

Chairman J. L. Beckel (New York Central System): Committee 15 wishes to express its deep regret in the loss of its chairman, Ralph W. Mabe. His untimely death has deprived the committee of an able chairman and the Association of a valuable member. His memorial may be found on page 442.

(Mr. Beckel then called upon, in turn, the various subcommittee chairmen, to present their reports.)

Assignment 1—Revision of the Manual, E. S. Birkenwald (Southern Railway), subcommittee chairman.

Mr. Birkenwald: The first items for revision have to do with the specifications for steel railway bridges. Rather than read these revisions, I would like to point out why the revisions are being made.

Mr. Sandberg: The research work on this project has been carried on at Purdue University, under the direction of Professor L. T. Wyly, assisted by the research staff of the AAR in the field testing of various bridges. This work has been in progress for about three years and we are now beginning to understand some of the features of this problem and possible remedies.

(Professor Wyly then gave a short talk, illustrated by lantern slides, on the work he is doing in the investigation of floorbeam hanger failures.)

President Schwinn: We wish to thank Professor Wyly for telling us so interestingly of the very fine work being done at Purdue.

Chairman Beckel: May I add a few remarks to Professor Wyly's words and call to the attention of the various railroads which have not reported any fatigue failures, that this may be due to the fact that to discover some of these fatigue failures requires quite a search. The original crack may occur at the lower rivet of the gusset plate, as illustrated by Mr. Wyly's talk. It requires quite a bit of investigation to find such a fatigue crack, and I am sure that railroads that have had this type of bridge in service for 50 years or so will find some fatigue cracks if they make such an investigation.

Assignment 8—Design of Metal Culverts of 60-In. Diameter and Larger, Including Corrugated Metal Arches, was presented by J. F. Marsh, (Chicago, Rock Island & Pacific), subcommittee chairman, who read a synopsis of the committee's report.

President Schwinn: Thank you, Mr. Marsh, and it will be so received.

Meyer Hirschthal (Consulting Engineer): I would like to ask a question on Article 12, near the bottom of page 505, in that second sentence, "Alternate structural units--." Don't you intend that to read "depth of corrugation of more than 1½ in?"

Mr. Marsh: Yes, we accept the change.

Assignment 9—Use of High-Strength Structural Bolts in Steel Railway Bridges, was presented by A. G. Rankin (Texas & Pacific), subcommittee chairman, who said that the report covered field test installations of over 1000 high-strength structural bolts.

Chairman Beckel: Mr. President, I would like to thank publicly the members of Committee 15, and especially the men who head up the subcommittees, for their wholehearted cooperation in the progress of the work of the committee. This concludes our report.

President Schwinn: I believe that this is our last committee report. I wish to thank you, Mr. Beckel, for your report to this attentive audience. You are now dismissed.

Impact (B) 2," the third line according to the Bulletin reads, "straight line variation from full effect as synchronous speed to 0.2 of the". The word "as" should be "at".

The Manual material for reapproval consists of material on Large Rivets and on Instructions for the Maintenance Inspection of Steel Bridges. The committee has reviewed this material and is offering it for reapproval as editorially changed on pages 444 and 445.

I move that this Manual material on pages 443, 444 and 445, as revised, be adopted by the Association.

(The motion was seconded)

(President F. S. Schwinn resumed the chair)

President Schwinn: Gentlemen, you have heard the motion. Is there any discussion of the proposed revisions?

Meyer Hirschthal (Consulting Engineer): I should like to suggest an editorial revision of the definition of "L" in Article 206 (b) on page 443 (page 15–8 in the Manual) as follows:

> For stringers, transverse floorbeams without stringers, longitudinal girders and trusses (main members)
>
> L = length, in feet, center to center of supports.
>
> For floorbeams, floorbeam hangers, subdiagonals of trusses, transverse girders, supports for longitudinal and transverse girders and viaduct columns
>
> L = length, in feet, of the longer adjacent supported stringer, longitudinal beam, girders or truss.

I think this would tend to simplify.

President Schwinn: Do you offer that as an amendment?

Mr. Hirschthal: I do. I think it would be an editorial change.

President Schwinn: What is the committee's view?

Mr. Birkenwald: I would like to see this suggestion in writing. I know that the committee will be glad to consider it.

[As the result of subsequent consideration of this matter by the chairman and vice-chairman of the committee, Mr. Hirschthal's suggestion was not adopted.]

(The motion to adopt the changes proposed relative to the Specifications for Steel Railway Bridges, on pages 443, 444 and 445, was seconded, put to a vote and carried.)

Mr. Birkenwald: You will find on page 445 through page 469, sections of the Proposed Specification for Movable Railway Bridges. The sections on power equipment, material, workmanship and erection are still to be published. But, they are now in the process of preparation and we expect to have them ready in the near future.

These sections of the proposed specification are given as information, and embody the latest information in the way of new equipment, new methods. In addition, the specifications have been somewhat rearranged to present the material in the best form for those who use it.

Chairman Beckel: These specifications for Movable Railway Bridges were presented as information, but we have all intentions of presenting them next year for adoption in the Manual. If there is anyone who would like to comment on these specifications, we would be glad to accept written comments for consideration.

Assignment 4—Stress Distribution in Bridge Frames—Floorbeam Hangers, was presented, with brief general comments, by C. H. Sandberg (Atchison, Topeka & Santa Fe), subcommittee chairman.

MEMOIRS

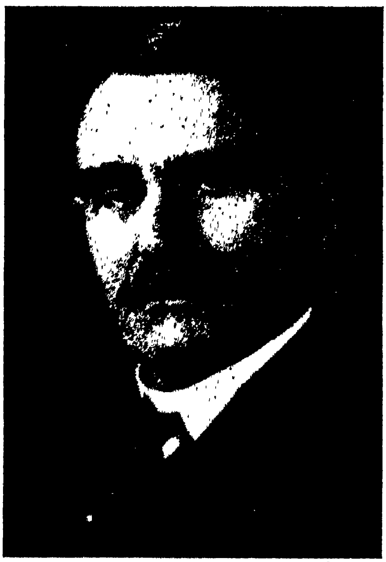
MEMOIR

Charles Adelbert Morse

Died April 12, 1949

Charles Adelbert Morse was born January 1, 1859, at Bangor, Maine. He was the son of Charles B. and Elsie (Emery) Morse. His engineering education was obtained at the University of Maine, where he was graduated in civil engineering in 1879.

Mr. Morse entered railway service with the Chicago, Burlington & Quincy Railroad in 1880, and worked with that road as a chairman, instrumentman and office man until November 1881. He was division engineer of the Mexican Central Railway from 1881 until the completion of that road in 1884. After working again for the Burlington for a year and a half, Mr. Morse, in January 1886, entered the service of the Atchison, Topeka & Santa Fe Railway. From January 1886 until July 1901 he served as transitman,



Charles Adelbert Morse

division engineer and resident engineer at Fort Madison, Iowa, and Pueblo, Colo.; July 1901 to February 1902, assistant to chief engineer, same road at Topeka, Kans.; February 1902 to March 1903, principal assistant engineer, Western Grand Division at La Junta, Colo., March 1903 to July 1903, engineer, Eastern Grand Division at Topeka; July 1, 1903 to July 8, 1904, acting chief engineer, at Topeka; July 8, 1904 to September 1, 1905, assistant chief engineer of same road; September 1, 1905 to September 1, 1906, acting chief engineer, Coast Lines at Los Angeles, Calif.; September 1, 1906 to November 1909, chief engineer, lines east of Albuquerque at Topeka, and November 1909 to April 1913, chief engineer of the Santa Fe system.

Mr. Morse went to the Chicago, Rock Island & Pacific Railroad in April 1913 as chief engineer, and remained with that road until his retirement at the age of 70, except for the period from September 1918 to June 1919 during federal control of the railways when he served as assistant director of operations, engineering and maintenance of way of the U. S. Railroad Administration.

MEMOIR

Hadley Baldwin

Died November 22, 1949

Hadley Baldwin was born on February 24, 1868. at Marshallton, Penna., near Philadelphia. His early education was obtained in local schools. He was a graduate of the University of Michigan in the class of 1893.

In September of that year, he entered the service of the Cleveland, Cincinnati, Chicago & St. Louis Railway, and spent all of his professional career with that road and its successor, the New York Central Railroad. In this service, he rose steadily, becoming in turn, masonry inspector, supervisor of track, engineer maintenance of way, engineer of construction, division superintendent, assistant chief engineer, chief engineer and consulting engineer.

Mr. Baldwin became one of the Charter Members, No. 73, of the American Railway Engineering Association, and served as director from 1919 to 1921 and 1928 to 1930, inclusive. He was also active in the committee work of the AREA, being first a member of Committee 9—Highways (then Committee 9—Grade Crossings) and chairman for a term ending with the 1928 Annual Meeting, and later a member of Committee 14—Yards and Terminals, and chairman for a term concluded at the 1940 Annual Meeting. In all of his service to the AREA, he gave seriously, sincerely and unselfishly and demonstrated his remarkable ability to think and write clearly.

Mr. Baldwin, in 1904, married Miss Emily Wilson of Mattoon, Ill., who, with two grown children, Miss Betty and Mr. Wilson Baldwin, all of Cincinnati, Ohio. survive him. In his many years of residence at Cincinnati, Mr. Baldwin interested himself and was especially active in the affairs of The Literary Club and the Better Housing League, and in the work of the Unitarian Church. These interests occupied much of his time and attention in the years following his retirement from active railroad service.

Hadley Baldwin's influence in all these spheres was great and good. His many friends regret his passing and are proud to have known him.

W. J. Hedley, *Chairman,*
M. J. J. Harrison,
L. L. Lyford,
Committee on Memoir

Report of the Secretary

March 1, 1950.

To the Members:

The report of the secretary covers the calendar year with respect to finances, the 12 months from February 1 to February 1 in the case of the membership record, and the period from March 1 to March 1 so far as other activities of the Association are concerned. Consequently, the report does not permit of a well defined comparison of one Association year with another. While such a comparison is normally of small concern, it is now of real interest because of curiosity on the part of not a few members as to the possibility of a recession during a year immediately following such intense activity as occurred during the Association's semi-centennial celebration which ended on March 17, 1949.

Because of such overlapping of records as that referred to above, the comparison is not too well defined, however it is clear enough to demonstrate that no such recession occurred. Indices that warrant this conclusion are:

An excess of receipts over disbursements in excess of $5000.

An increase in membership.

An increase in the personnel of committees.

An appreciable increase in the printed pages of committee reports and a moderate increase in the number of pages of material offered for adoption and publication in the Manual.

An increase in the revenues from the sale of the Association's publications.

Details of these various indices of the Association's well-being are set forth on this and following pages. The report also focusses attention on the formidable task which now confronts your committees and the secretary and his staff in the rearrangement and reprinting of the Manual within the next three years.

Finances

The financial statement for the calendar year of 1949, which appears in full on following pages, may be summarized as follows:

Receipts	$62,081.61
Disbursements	57,075.63
Excess of receipts over disbursements	$ 5,005.98

Anyone who examines the financial statement in detail must necessarily accept it solely as an accounting of the operations of the Association for the particular year involved. Because of the extraordinary activities occasioned by the semi-centennial celebration, both the revenues and the expenditures were distinctly out of the ordinary. Consequently, it is not possible to point to any trends that would be indicative of the level of either the revenues or the disbursements in the years to come. As a matter of fact, the operations of the Association are such as to bring about rather marked variations in both income and outgo from year to year. Thus in 1952 or 1953 it will be

Charles Morse was one of the most able and distinguished railway engineers of his time. His wide experience ably fitted him in both the construction and maintenance of railways. He left many monuments to his ability on the roads which he served long and faithfully, especially the Santa Fe, with which he was connected for 27 years, and the Rock Island, which he served for 16 years. He was in responsible charge of engineering on both of these properties during the years when rehabilitation and improvement programs were vigorously prosecuted and many changes in line and grade on those two railways bear the imprint of his genius as a railway engineer.

Mr. Morse went to the Rock Island at the time that the physical condition of the property was at a low ebb and shortly thereafter the road passed through a receivership and federal control. But by 1929 through his personal persistent efforts, he had succeeded in getting the property into a high standard of physical condition. This was accomplished through a comprehensive program of tie, ballast and rail renewals, and the increased use of mechanical facilities.

In extensive double-track work on both the Santa Fe and Rock Island he evinced marked ingenuity in taking advantage of the topography of the country, always building the added track with a view to securing the lowest grade in the direction of the heaviest traffic, reversing from right hand to left hand operation on sections of double track where necessary to obtain the desired result. Such expedients greatly reduced the cost of construction as well as operation and future maintenance.

He joined the AREA in 1904, served as director from 1913 to 1916 and vice-president from 1916 to 1918. He was president from March 1918 until March 1919, and was elected Honorary Member in 1937.

He was a member of Committee 13—Water Service, from 1906 to 1911; Committee 4—Rail, from 1912 to 1919, and again in 1924; and Committee 24—Cooperative Relations with Universities, from 1925 to 1934.

By nature a "Maine yankee," he invariably succeeded in securing the maximum results for his expenditures, both in construction and maintenance. Those who were associated with Mr. Morse were impressed with his ability, loyalty and integrity. He was a man of positive convictions and "stood by his guns," even if opposed by his superiors, only to be the victor in showing the justness of his position. It was not surprising, therefore, that he manifested leadership in the Board of Direction in resisting the efforts of the American Railway Association during the closing days of World War I to include the AREA among the other associations of railway officers that were marked for absorption as wholly dependent units of the ARA. Because of this opposition steps were taken to effect a cooperative working arrangement between the AREA and the ARA (since continued with its successor, the AAR) under which the AREA retains its identity and individuality as an association of railway engineers. He was a pioneer in railway construction, rehabilitation and maintenance. He left a valuable heritage to the railway engineering profession.

Mr. Morse was loved and respected by his superior officers and by the members of his department, and by all members of the AREA who had the privilege of knowing him.

G. J. Ray, *Chairman,*
L. C. Fritch
J. G. Wishart
Committee on Memoir.

no basis for a prediction regarding the time when the total of the life members will attain a state of equilibrium. A straight line increase was disturbed through 1943 and 1944 by the effect of the temporary decline in retirements during the mid-war years; otherwise the rate of growth would have varied little from an average of 19.2 per year. The marked increase in the membership during 1948 and the early part of 1949 will of course have no effect on the number of life members for many years to come.

	1946	*1947*	*1948*	*1949*	*1950*
Life	246	277	294	325	339
Member	1564	1618	1686	2263	2276
Associate	262	287	317	275	280
Junior	35	34	37	145	158
	2107	2216	2334	3008	3053

Although the Association is now completing its 51st year, the membership roll still includes eight charter members. They are:

T. L. Condron
L. C. Fritch, past president and past secretary
E. C. Macy
William Michel
F. L. Nicholson, past director
W. B. Poland
A. D. Schindler
E. F. Wendt, past president

Deaths during the year totaled 44, as recorded in the roster of deceased members appearing at the end of this report. Among those who died during the year were three charter members, F. M. Patterson, W. J. Wilgus and Hadley Baldwin, the latter having served two terms as director. Also included were C. A. Morse, president from March 1918 to March 1919, and R. W. Mabe, chairman of the Committee on Iron and Steel Structures.

Publications

The seven bulletins ending with February 1950 contained 1176 pages of text matter, exclusive of advertising, compared with 890 pages for the seven preceding bulletins, and 1014 two years ago. The high total for the last year is accounted for largely by the unusual size of the Golden Jubilee Year Book (Bulletin 480 for March 1949) which contained a special section of 120 pages devoted to the history of the Association. Vol. 50, 1949, of the Proceedings contained 963 pages, compared with 866 pages in Vol. 49, and 1040 pages in Vol. 48.

The committee reports published for presentation at the convention in March 1950 covered 684 pages in Bulletins 483 to 486, incl., to which should be added 86 pages of reports on research projects sponsored by groups in which AREA committees are represented. These appeared in Bulletins 481 and 482.

Contents of Bulletin 481, June–July 1949

Effect of Various Fasteners on the Fatigue Strength of a Structural Joint
Tests of Three Methods of Attaching Tie Plates
Preliminary Report of Committee 3—Ties—Renewal Statistics
Charles Adelbert Morse—A Memoir

necessary to reprint the Manual in its entirety, and this reprinting will involve such marked alterations as to make it necessary to issue a complete new set of sheets to every holder of a Manual. It goes without saying that the expenditures in the year in which this reprinting is done will far exceed the revenues. Consequently, any excess in the revenues over disbursements in prior years may be considered as accumulations designed to offset anticipated deficits.

An extra member of the staff, employed to carry the additional load imposed by preparations for the semi-centennial celebration and the extraordinary increase in membership, was released during the last summer, thus decreasing the Association's office force from seven to six.

COMPARISON OF RECEIPTS AND DISBURSEMENTS FOR A 15-YEAR PERIOD

	Receipts	*Disbursements*	*Net Gain*
1935	$29,001.00	$30,110.00	$1,109.00*
1936	28,643.00	34,662.00	6,019.00*
1937	36,523.00	32,200.00	4,323.00
1938	28,422.00	23,394.00	5,028.00
1939	28,189.00	23,847.00	4,342.00
1940	28,272.00	26,451.00	1,821.00
1941	32,433.00	29,384.00	3,049.00
1942	31,500.00	26,692.00	4,808.00
1943	28,736.00	23,809.00	4,927.00
1944	30,492.00	26,534.00	3,958.00
1945	32,305.00	29,305.00	3,000.00
1946	28,836.00	34,583.00	5,747.00*
1947	46,993.00	46,989.00	4.00
1948	57,741.00	53,062.00	4,679.00
1949	$62,081.00	$57,075.00	$5,005.00

* Deficits.

Membership

The membership record for the period from February 1, 1949, to February 1, 1950, was as follows:

Members on the rolls February 1, 1949			3008
New members			222
Reinstatements			21
			3251
Deceased	44		
Resigned	33		
Dropped	85		
Juniors transferred and dropped	36		198
Net gain		45	
Membership February 1, 1950			3053

The classification of the membership as of the last five years, as shown below, has not changed markedly during the last year. There has been an encouraging increase in the number of Juniors, keeping in mind that tenure as a Junior is of short duration. The number of life members increased from 325 to 339 during the year, and a study of a graph of the increase in the number of life members during the last 12 years affords

fall of 1949. Thus, 945 members now occupy 1036 places on the 21 committees, compared with 911 men in 1003 places a year ago.

As explained in the last report of the secretary, the pronounced increase in the size of the committees was undertaken as a means of meeting the greatly stimulated demand for places on committees. Also, for the purpose of insuring an equitable distribution of the assignments it became necessary to set up rules which impose specific limitations on the appointment of members to more than one committee, on the number of men from individual railroads who may be assigned to any one group, etc. Furthermore, to apply such rules it became necessary to set up a system of records which would show at a glance the names of the members from the various railroads and from non-railroad companies who are identified with each of the committees, to supplement the card index record of all persons included in the total committee personnel.

Also because several of the committees have their full quota of 60 members it has been necessary to set up waiting lists, with provision in some cases for the informal status of "visiting member" of a committee. It is necessary to keep in mind, also, in considering what is involved in policing a committee membership of more than 1000 places that the records are subject to constant revision because of the day-to-day changes that take place in the personnel of the railroads. It is not surprising, therefore, that the increase in the size of the committees has added greatly to the work of the committee chairman. The task of selecting from the roster of his committee each fall the men who should be released so as to make places for others who wish to be admitted calls for an intimate knowledge of interest shown and effort applied to the work, with a realization that the opportunity for unjust action is greatly increased with an increase in the number of persons involved.

Realizing that an increase in the size of any organization calls for the clearest possible definition of the administrative channels and that the General Rules for the Preparation, Publication and Presentation of Committee Reports were no longer in accord with current practice, the Board of Direction instituted a thorough review of these regulations with a view to the development of something that would more nearly meet the needs of the time. This study led to the conclusion that some rules *per se* were needed, but that there was greater need for a clear exposition of the aims and requirements, in other words, a thoroughgoing compilation of the things that committee men, especially chairmen and subchairmen, must know if they are to conduct their work effectively. Also, to insure that this information would be most readily available when it was needed, it was necessary to set it off with a large number of topical headings. The result of this effort was presented for the first time in the Committee Roster and Assignments pamphlet for 1950 under the heading Information for the Guidance of Committees.

Measured by the number of meetings, committee activity in 1949 was on a parity with that of the previous year. There were 51 meetings of full committees, compared with 48 a year earlier. In 1949 one committee held four meetings, 10 had three meetings each, 7 held two each and 3 held only one.

Of the 51 meetings, 32 were held in Chicago, 2 in New York and 2 in Buffalo, N. Y., while 15 others were held in as many different places, including one in Montreal, Que. The marked increase and wider territorial distribution of the members of committees has given rise to considerable speculation as to possible advantages to accrue from the holding of occasional meetings in the west, or southwest, since this practice would encourage attendance by members who are located far away from places normally chosen for the meetings. But experience indicates that this expedient results in a

Contents of Bulletin 482, September–October 1949

The Manual

The supplement embracing the revisions authorized at the annual meeting in March 1949 contained 151 new sheets for insertion in the loose-leaf Manual and was accompanied by instructions for the removal of 144 old sheets, thus resulting in a net increase of 7 sheets. The Manual has now been in loose-leaf form for almost 14 years, and in that time 1797 new sheets have been issued and 1612 have been withdrawn, so there has been a net increase in the size of the book of 185 sheets. As pointed out in the report of the secretary a year ago, it has not always been possible to introduce the new material into the chapters in locations that would insure a logical sequence of the subject matter, and two chapters have already been reprinted to permit of a complete rearrangement. The recasting of other chapters is in process as well as a general revision of much of the text matter.

These changes, together with the need of a resetting of substantially all of the type, which has become worn from repeated reprintings, point to the desirability of changes in style (modern practice with respect to abbreviations, use of numerals, etc.), so that it would be necessary to replace all of the sheets in the Manuals issued to date. This program calls for an enormous amount of work following some very careful planning, together with the scheduling of major revisions by the committees of their respective chapters well in advance of the actual reprinting. The exact timing has not yet been determined, since this is contingent on the estimated date of depletion of the present stock of Manuals; however it is certain the job will have to be completed not later than some time in 1953.

Record of Manual Supplements

Supplement	*New Sheets Issued*	*Old Sheets Withdrawn*	*Net Increase*
1937	110	69	41
1938	151	121	30
1939	128	95	33
1940	185	139	46
1941	148	120	28
1942	144	149	–5
1943	176	158	18
1944	131	109	22
1945	44	45	–1
1946	127	147	–20
1947	167	184	–17
1948	135	132	3
1949	151	144	7
Total	1797	1612	185

Work of the Committees

Although the personnel of the committees as listed in the Committee Roster and Assignments issued in December 1948 was the greatest in the history of the Association, a further increase in the number of members assigned to committees was effected in the

ENGINEERING DIVISION ALLOTMENTS FOR RESEARCH

	1948 Budget	1949 Budget	1950 Budget
Committee on Rail			
Transverse Fissure Investigation	$ 5,000	$ 5,500	$ 5,500
Investigation of Shelly Spots	13,000	13,500	15,500
Rail Investigation Committee	8,996	9,808	9,100
Service Tests of Joint Bars	8,500	9,076	4,500
Rolling Load Tests of Joint Bars	8,500	9,000	9,000
Investigation of Driver Burns	6,000	3,000	4,000
Rail Design Investigation	15,800	18,545	14,800
Total	$ 65,796	$ 68,429	$ 62,400
Committee on Track			
Stresses in Tie Plates	$ 10,620	$ 11,028	$ 8,000
Bolt Tension and Joint Lubrication	4,800	5,000	5,000
Corrosion from Brine Drippings	1,000	10,000	2,500
Stresses in Manganese Frogs	5,380	5,245	5,245
Tests of Rail Anchorage	3,180	5,000	0
Tie Plate Fastenings	10,800	10,688	9,000
Total	$ 35,780	$ 46,961	$ 29,745
Relation Between Track and Equipment			
Rail and Wheel Gage and Contour	$ 10,400	$ 8,000	$ 6,500
Relation Wheel Load to Wheel Diameter	5,500	5,500	5,500
Flat Spot Investigation	0	0	0
Lateral Forces from Locomotives	10,700	2,000	0
Relation of Wheel Pressures to Track Curvature	0	15,000	0
Total	$ 26,600	$ 30,500	$ 12,000
Structural Projects			
Impact Investigation	$ 79,500	$ 97,792	$ 80,000
Riveted and Bolted Structural Joints	5,500	10,000	10,000
Strength of Floor Beam Hangers	10,000	10,000	10,000
Rocker Shoe Assemblies	0	4,000	2,000
Column Research Council	0	4,000	6,000
Fatigue Strength of Butt Welded Beams	2,000	0	0
Waterproofing Investigation	10,000	15,343	6,000
Total	$106,500	$141,135	$114,000
Roadway and Ballast			
Roadbed Stabilization	$ 20,000	$ 26,496	$ 24,900
Ballast Tests	0	6,700	0
Total	$ 20,000	$ 33,196	$ 24,900
Miscellaneous			
Research Office	$ 16,164	$ 31,236	$ 31,000
Electrolitic Corrosion of Steel in Concrete	1,000	1,000	0
Wear and Splitting of Ties	20,000	20,000	20,000
Total	$ 37,164	$ 52,236	$ 51,000
GRAND TOTAL	$291,840	$372,457	$294,045

marked falling off in the attendance by those who are best served by meetings in central locations. The Board of Direction has given the matter much thought, but to date has been unable to hit upon any plan to mitigate the effect of the uneven distribution of the membership over the continent of North America. In the meantime committee and subcommittee chairmen are urged to recognize the fact that busy railway men cannot be expected to travel 1500 to 2000 miles to attend meetings and that due consideration should be given to comments and criticisms transmitted by mail.

Classification of Material in the Committee Reports

	1945	*1946*	*1947*	*1948*	*1949*	*1950*
Revisions of the Manual—minor	6	10	13	36	21	16
Revisions of the Manual—major	..	7	11	22	16	8
Reapproval of Manual material	..	..	..	23	7	5
New Manual material—minor	1	..	2	1	2	2
New Manual material—major	2	3	3	4	2	4
New Manual material—tentative	2	1	5	7	2	4
Information	33	32	33	29	35	49
Reports on research work	12	14	15	16	19	18
Reports on service tests	4	5	6	3	7	7
Statistical data	3	2	2	3	4	2
Analytical studies	2	2	2	8	14	7
Bibliographies	2	2	2	2	2	3
Brief reports of progress	7	7	13	16	20	13
War emergency provisions	4	1	..	..	..	..
	78	86	107	170	151	138

Research Work

With respect to research work in which the committees of the AREA have an interest, the outstanding development of the year was the construction of the Association of American Railroads' laboratory on the grounds of Illinois Institute of Technology in Chicago at a cost of $600,000, not including the expenditures for equipment and furnishings. Effective March 1, 1950, this laboratory will be the headquarters for the research engineer of the Engineering Division and the members of his staff. Because of this extraordinary outlay in one year and the marked falling off in railway earnings, the 1950 appropriations for research for the Engineering Division, AAR, were curtailed markedly, compared with the appropriation for 1949. However, the total of the allotments, as shown in the table by years from 1938 to date, is greater than in any other previous year.

Total Allotments for Research Work, Engineering Division, 1938–1950

1938	$ 78,158	1945	$138,110
1939	77,650	1946	159,510
1940	69,250	1947	234,428
1941	95,150	1948	291,840
1942	87,932	1949	372,457
1943	98,445	1950	294,045
1944	109,050		

W. S. Lacher,
Secretary.

H. M. LULL
Retired Executive Vice-President, Southern Pacific Lines in Texas and Louisiana, Berkeley, Calif.

R. W. MABE
Assistant Chief Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, 3, Tenn.

D. T. MACK
Architect, Delaware, Lackawanna & Western Railroad, Hoboken, N. J.

J. R. MANLEY
Architectural Designer, New York Central System, New York, 17, N. Y.

W. R. H. MAU
Assistant General Purchasing Agent, Missouri Pacific Lines, St. Louis, 3, Mo.

H. J. MOORE
Division Engineer, Atchison, Topeka & Santa Fe Railway, Newton, Kans.

C. A. MORSE
Retired Chief Engineer, Chicago, Rock Island & Pacific Railroad, Chicago, 37, Ill.

J. E. O'DONNELL
Assistant Chief Engineer, Central Vermont Railway, St. Albans, Vt.

F. M. PATTERSON
Newfane, Vt.

J. F. PRINGLE
Vice-President and General Manager, Canadian National Railways, Toronto, 1, Ont.

F. R. PUDER
7210 South Princeton Ave., Chicago, 21, Ill.

W. M. RAY
Retired Senior Assistant Engineer, Baltimore & Ohio Railroad, Pittsburgh, 22, Pa.

H. E. RIGGS
Honorary Professor of Civil Engineering, University of Michigan, Ann Arbor, Mich.

J. E. ROGAN
Retired Assistant Engineer Maintenance of Way, Illinois Central Railroad, Chicago, 49, Ill.

A. H. RUDD
Retired Chief Signal Engineer, Pennsylvania Railroad, Lakeville, Conn.

CHARLES SILLIMAN
Consulting Engineer, 210 East Fornance St., Norristown, Pa.

E. SULLIVAN
Assistant General Manager, Missouri Pacific Railroad, St. Louis, 3, Mo.

E. B. TEMPLE
Retired Chief Engineer, Eastern Region, Pennsylvania Railroad, Swarthmore, Pa.

T. G. TOWNSEND
50 East 58th St., New York, 22, N. Y.

G. H. TROUT
Retired Assistant Chief Engineer, Union Pacific Railroad, Omaha, 3, Nebr.

W. A. WEBBER
Division Engineer, Great Northern Railway, Great Falls, Mont.

W. D. WIGGINS
Retired Vice-President -- Engineering, Pennsylvania Railroad, Merion, Pa.

W. J. WILGUS
Colonial Inn, Claremont, N. H.

Deceased Members

HADLEY BALDWIN
Retired Special Engineer, New York Central System, Cincinnati, Ohio

J. Q. BARLOW
Consulting Engineer, 2803 Woolsey St., Berkeley, 8, Calif.

K. R. BECK
Chief Masonry Inspector, Illinois Central Railroad, St. Louis, 3, Mo.

A. J. BOASE
Manager, Structural Bureau, Portland Cement Association, Chicago, 10, Ill.

T. N. CHAN
Instrumentman, Gulf, Mobile & Ohio Railroad, Bloomington, Ill.

W. L. CODINGTON
District Engineer, Canadian Pacific Railway, Winnipeg, Man.

E. H. CONNOR
Retired Vice-President and Consulting Engineer, The Missouri Valley Bridge & Iron Company, Leavenworth, Kans.

W. R. EDWARDS
Retired General Bridge Inspector, Baltimore & Ohio Railroad, Baltimore, 17, Md.

C. A. ELLIS
Retired Professor of Structural Engineering, Purdue University, Evanston, Ill.

J. W. FLEMING
Assistant Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, 19, Pa.

C. J. FREEMAN
Assistant District Engineer, Northern Pacific Railway, Seattle, 4, Wash.

R. E. FRISTOE
Chief Engineer, Galveston Wharves, Galveston, Tex.

J. J. GALLAGHER
Engineer Maintenance of Way, Missouri–Kansas–Texas Railroad Company of Texas, Dallas, Tex.

W. R. GILLAM
Division Engineer, Illinois Central Railroad, Champaign, Ill.

G. M. HELMIG
Trainmaster, Missouri Pacific Railroad, Little Rock, Ark.

WARREN HENRY
Chief Engineer, Illinois Commerce Commission, Springfield, Ill.

S. J. HOOD
Chief Engineer, Western Australian Government Railways, Railway Offices, Perth, Western Australia

K. P. HOWE
Assistant Engineer Water Supply, Louisville & Nashville Railroad, Louisville, 1, Ky.

H. N. HUNTSMAN
Chief Engineer, Litchfield & Madison Railway, Edwardsville, Ill.

A. S. KENT
Retired Chief Engineer, Chicago, Indianapolis & Louisville Railway, South Bend, 15, Ind.

R. F. LOGAN
Chief Engineer Maintenance of Way and Structures, Southern Railway System, Knoxville, 24, Tenn.

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1949		$106,205.53
Receipts during 1949	$62,081.61	
Paid out on Audited Vouchers	57,075.63	
Excess of Receipts Over Disbursements		5,005.98
Balance on hand December 31, 1949		$111,211.51
Consisting of		
Bonds at cost	$98,385.50	
Cash in Northern Trust Company Bank	12,801.01	
Petty Cash	25.00	
		$111,211.51

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1949 and find them to be in accordance with the foregoing statement.

C. A. Bick,
P. D. Mitchell,
Auditors

GENERAL BALANCE SHEET

Assets	*1949*	*1948*
Due from Members	$ 123.00	$ 361.00
Due from Sales of Publications	145.40	81.00
Due from Advertising	317.00	127.50
Inventory of Furniture and Fixtures	966.85	863.16
Inventory of Publications on hand (estimated)	500.00	704.00
Inventory of Manuals	6,732.00	9,630.50
Inventory of Track Plans	2,159.00	2,722.00
Inventory of Paper Stock	1,001.80	1,502.00
Investments (at cost)	98,385.50	98,385.50
Investments Interest Accrued	567.41	567.41
Cash in Northern Trust Company Bank	12,801.01	7,795.03
Petty Cash	25.00	25.00
Total	$123,723.97	$122,764.10
Liabilities		
Members' Dues Paid in Advance	$ 336.50	$ 539.25
Surplus	123,387.47	122,224.85
Total	$123,723.97	$122,764.10

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1949

Balance on hand January 1, 1949 .... $106,205.53

RECEIPTS

Membership Account			
Entrance Fees	$ 2,240.00		
Dues	39,963.75		
Binding Proceedings	217.50		
		$42,421.25	
Sales of Publications			
Proceedings	$ 1,438.16		
Bulletins	2,109.47		
Manuals	4,803.50		
Specifications	1,927.16		
Track Plans	872.45		
Hand Books	56.00		
		$11,206.74	
Advertising			
Publications		$ 5,587.97	
Interest Account			
Interest on Investments	$ 2,404.84	$ 2,404.84	
Miscellaneous		$ 460.81	
Total		$62,081.61	

DISBURSEMENTS

Salaries	$17,152.18		
Proceedings	9,400.75		
Bulletins	7,543.23		
Stationery and Printing	2,234.94		
Rents, Lights, etc.	1,020.00		
Supplies	179.77		
Postage	1,132.90		
Refunds of dues, etc.	77.45		
Audit	400.00		
Pension	1,200.00		
Social Security and Unemployment Taxes	506.70		
Manual	1,795.47		
Track Plans	233.25		
Committee and Officer's Expense	196.50		
Annual Meeting Expenses	1,023.79		
News Letter	2,482.18		
50th Anniversary	9,942.05		
Hand Books	......		
Miscellaneous and Extraordinary	554.47		
Total		$57,075.63	
Excess of Receipts over Disbursements			$ 5,005.98
Balance on hand December 31, 1949			$111,211.51

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school without graduation shall be considered as equivalent to one-half year of active practice.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals with railway problems.

(d) An editor of a trade or technical magazine who in the discharge of his regular duties deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. Associate

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than twenty-one (21) years of age and shall be an engineering employee of a railway corporation who has had not less than three (3) years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this Association shall terminate at the end of the calendar year in which he becomes thirty (30) years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

American Railway Engineering Association

CONSTITUTION

Revised to June 15, 1948

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than twenty-five (25) years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be payable to the Association on account of Junior Membership.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association, except those of voting and holding elective office.

Article III

ADMISSION, RESIGNATION, EXPULSION AND REINSTATEMENT

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the application shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

3. Officers Elected Annually

(a) There shall be elected at each annual convention a President, one Vice-President and four Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from the members or past members of the Board of Direction. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past-Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be fifteen dollars ($15.00).

(b) The annual dues for each Junior Member shall be seven dollars and fifty cents ($7.50).

(c) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, twelve Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the two latest living Past-Presidents continuing to be members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

(d) Provided, however, that in the first Association year following the amendment of the Constitution by the inclusion of this paragraph, the Board of Direction shall include ten Directors and the four latest living Past-Presidents continuing to be members, and that in the second Association year it shall include eleven Directors and the three latest living Past-Presidents continuing to be members.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1 President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2 Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

Reading of the Minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of Committees
Unfinished Business
New Business
Installation of Officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairmen, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

Information for the Guidance of Committees

(Revised November 8, 1949)

The following information and regulations for the guidance of committees are designed to obtain the maximum benefits from the efforts of the voluntary workers who make up the personnel of such committees. They are designed to effect a continuity of effort in committee work throughout the entire year, under a plan whereby the personnel of the committees and their respective outlines of work are made public on or before the beginning of the calendar year, thus enabling the work to be continued without interruption, although the new personnel and subject assignments do not become officially effective until the beginning of the "Association Year" which starts with the close of the annual convention.

These regulations also take into account the fact that the publication of the committee reports must be spread out over a period of four months so as to give the members a reasonable length of time in which to study such reports in advance of the convention. They also make due allowance for the fact that the printing of the Association's committee reports requires considerable time.

Subjects Re-assigned Annually

The outline of work of each committee shall be reviewed annually. To this end, each committee shall review suggestions for new subjects submitted by the members thereof and such suggestions as receive the approval of the committee shall be submitted by the chairman to the secretary of the Association not later than October 1, together with the committee's recommendations covering the withdrawal or continuation of current assignments.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Outline of Work which shall have the responsibility of authorizing the subject assignments to the various committees. Deviation from assignments thus authorized may be made during the course of the year only upon the authority of the Committee on Outline of Work.

Committee Personnel Reorganized Annually

The personnel of each committee shall be reorganized annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee or who do not render service by correspondence or who do not return letter ballots will be dropped. To this end the chairman of the committee shall submit to the secretary of the Association not later than October 1 a list of the members who have been delinquent in service to the committee, as well as a list of the names of members of the Association who have been recommended for appointment to the committee by members thereof.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Personnel which shall have the duty of appointing the committee personnel.

No additions to the personnel of committees will be made following the publication of the roster, except as provided for under the heading of "Guests."

Three-Year Terms for Chairmen

The terms of chairmen and vice-chairmen shall be three years in each position. Chairmen completing their three-year term shall recommend to the Board Committee on

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

Subcommittees

In general, the committees are organized to conduct their work by the appointment of one subcommittee for each subject assignment. If deemed advisable, any subject may be subdivided into several parts and a separate subcommittee assigned to each part. Committees may find it of advantage to create a subcommittee on personnel as well as a subcommittee on new subjects.

Collaboration

Subjects the nature of which clearly indicates the possibility of overlapping interest of two or more committees, carry an appended clause reading: "collaborating with Committee ...." It is the duty of the chairmen of the committees having an assignment carrying this instruction to take the initiative in effecting such collaboration;—first, by requesting the appointment of representatives of the other interested committee or committees, and second, by submitting copies of the report to them for comment. Regardless of whether the assignment specifically requires collaboration, committees shall be on the alert to obtain the advice and assistance of other committees in dealing with any subject that imposes any questions of possible overlapping interest or responsibility.

A committee undertaking revision of its Manual chapter should request collaboration of any committee that participated in the original development and adoption of the material under revision. The secretary of the Association will provide information concerning such earlier collaboration.

Work of the Committees

Objectives

The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

Planning the Work

In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions contained in such circulars should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. The circulars should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Research

Requests for appropriations for the conduct of research work should be sent to the secretary of the Association with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time

Personnel two or more nominees for the chairmanship and vice-chairmanship, with assurance of acceptance from such nominees if appointed by the Board Committee.

Size of Committees

The total membership of any committee shall be limited to 60. In determining membership of a committee, railroads having no more than 50 Association members may have not more than two members on any committee; railroads having 51 to 100 members may have not more than 3 members on any committee; railroads having more than 100 members may have not more than 4 members on any committee.

Retired Members

No member who has retired from active service shall serve on a committee more than 3 years following retirement. However, such member may continue to attend meetings as a guest, subject to the approval of the committee chairman.

Associate Members

No company will be permitted to have more than one Associate representative on any committee; company representation shall not necessarily be continuing.

Membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. However, committees are not required to reduce the number of Associates immediately for the purpose of complying with this rule, but no Associates may be added as long as the proportion exceeds 10 percent.

Guests

Chairmen of committees may invite persons not members thereof to attend meetings. However, such guests shall not receive subcommittee assignments, are not entitled to vote, and do not acquire any priority with respect to committee membership.

Service on More Than One Committee

No member of the Association shall serve on more than one committee, except that a member may serve on two committees if one or both of the committees are among the following—Committee 3—Ties; Committee 7—Wood Bridges and Trestles; Committee 17—Wood Preservation; Committee 20—Uniform General Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses.

Organizing the Committees

The new outline of work and personnel of committees become effective each year with the close of the convention in March. However the pamphlet containing this information is issued not later than January 1, in order that committees may be reorganized promptly for the new year's work. Usually this information will be available to the chairmen in tentative form at least 30 days in advance of publication.

It is the duty of the chairman of the committee to notify new members promptly of their appointment and old members of their reappointment or release. It is also his duty to reorganize the subcommittees without delay. However, in the Association year in which his term as chairman expires, he may call on his successor for advice and assistance in this regard.

The chairman shall furnish the secretary of the Association with two copies of the schedule of subcommittee personnel and also of any subsequent revisions thereof.

He shall also send to the secretary of the Association copies of all notices of committee meetings as well as minutes thereof.

Letter Ballot Required of Committee

Any material offered by a committee for adoption and publication in the Manual, or any recommendation for the revision of or removal from the Manual of material appearing therein, shall appear in full in a report of the committee that is published not less than 30 days before the annual meeting at which it is to be presented. Any action recommended by a committee with respect to the adoption, revision or withdrawal of Manual material must have received prior endorsement by the committee in the form of a two-thirds affirmative vote of all members of the committee, such vote to be taken by letter ballot. Associate members of the committee are not entitled to vote.

Form of Report

Committee reports shall be prepared in accordance with the Style Standards for Committee reports.

Publication of Reports

Dates for Filing and Publication of Reports

To insure the orderly publication of the reports in accordance with a predetermined schedule, it is necessary that chairmen file complete reports with the secretary of the Association on or before the dates specified in the Committee Roster and Assignments pamphlet. The manuscript of the report must be furnished in duplicate. Piecemeal filing of reports by subcommittee chairmen is permissible only under special arrangement with the secretary in writing.

Written Discussions

Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Oral Discussions

When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Consideration of Committee Reports

Presentation of Reports Offered as Information

Reports offered as information will be presented by title or by a brief outline of the contents. Comments or criticisms may be offered from the floor.

Presentation of Manual Material

Material submitted for adoption and publication in the Manual shall be presented by reading the title and subtitles, but the presiding officer may, upon request, authorize the reading of specific portions of the material being offered.

Action on Reports

No formal action is to be taken by the convention on material submitted as information, whether in the form of a progress or final report.

Action on material submitted for adoption and publication in the Manual will be one of the following:

to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and, (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigation. A request for funds to continue or complete an investigation shall include a statement of the results obtained to date.

Maintaining Manual Up to Date

Each committee shall critically review the material in its chapter of the Manual at such intervals as to insure that it is kept up to date. It shall resubmit all Manual material for revision or reapproval at intervals of not more than 10 years.

Reports

Nature of Report

Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, also, it may be advisable to submit as information material in the form of recommended practice with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the material a year later for adoption.

Reports on All Assignments Not Necessary

Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on those assignments regarding which pertinent information has been developed.

Avoid Repetition of Report Material

Reports of information, supplementing previous reports of progress, may include a brief review of material previously presented, but should avoid extended repetition of such material.

Nature of Manual Material

The material adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Offering Material Previously Published

Material offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years unless the material being offered appeared in substantially identical form not more than one year before being submitted for adoption.

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(a) Adoption as a whole as presented.
(b) Affirmative action on the amendment of a part or parts of the material presented, followed by adoption as a whole as amended.
(c) Adoption of a part, complete in itself, and referring the remainder back to the committee.
(d) Recommittal with or without instructions.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

Letter Ballot of Membership

When and as required, recommendations for the adoption, deletion or revision of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

The Board of Direction, acting under the provisions of paragraphs 6 (a) and 11 of Article VII of the AREA constitution, has the authority to amend, delete or revise Manual material at any time, subject to later confirmation or rejection by the membership, submission to the membership to be effected either by means of a letter ballot immediately following such Board action, or by a motion presented at the annual meeting.

Review by Association of American Railroads

All material adopted for publication in the Manual and all recommendations for the revision or withdrawal of Manual material shall be reviewed by the Association of American Railroads before distribution is made thereof to holders or purchasers of the Manual, or parts thereof.

Publication of Annual Supplement

Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those that have been withdrawn by action of the Association.

Publication of Abstracts by Technical Journals

The following rules will govern the releasing of material for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released for publication until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication in technical journals after issuance in the bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or committees presenting such material.

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